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PUBLIC HEALTH.

TENTH REPORT

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL.

WITH

APPENDIX.

1867.

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Presented pursuant to Act of Parliament.

LONDON:
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1868.

TO THE LORDS OF HER MAJESTY'S MOST HONORABLE PRIVY COUNCIL.

My Lords,

In obedience to the Public Health Act, 1858, I have the honour of herewith submitting to Your Lordships, for presentation to Parliament, my Report of the proceedings which Your Lordships under that Act directed to be taken during the year 1867.

I am, my Lords,
Your Lordships' obedient servant,
JOHN SIMON.

Medical Department of the Council Office,
8, Richmond Terrace, S.W.;
March 31st, 1868.

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MEDICAL OFFICER'S REPORT.

I.—The Administration of the Diseases Prevention Act.

Diseases Prevention Act.

The Diseases Prevention Act, which in the summer of 1866 had been put in force by Her Majesty's Government on account of the diffusion of Asiatic Cholera in England, was kept in operation throughout the whole year 1867 by successive Acts of the same authority; and my Lords of the Council, on each of the half-yearly occasions when the Act was ordered to continue in force, provided that also the Medical Relief Regulations of 1866 (as given in App. No. 5 of my last annual Report) should continue. Those regulations, for their first issue, had been carefully so constructed that their renewal from time to time should not make any further claim on local authorities for trouble or expense, except in so far as new outbreaks of cholera might arise; and, subject to this condition, it appeared better that the Regulations should continue in force, ready for immediate application to any such outbreak, than that risk should be run of emergencies perhaps to arise after their lapse. Fortunately the year 1867 passed without any noticeable repetition of the epidemic experience of 1866. In this state of the case a further continuance of the Regulations seemed unnecessary, and at the date of my present writing the Diseases Prevention Act has ceased to be in force.

II. The Regulation and Superintendence of Public Vaccination.

Vaccination.

In 1867, as in previous years, my Lords superintended the Public Vaccination of England; including (1) the proceedings of local authorities and officers in that matter; and (2) the establishment by which the national supply of vaccine lymph is maintained; and (3) the arrangements which give effect to the Order of Council regulating the qualifications of public vaccinators.

1. *District-Inspections, and Awards to Public Vaccinators*

District Inspections, and Awards to Vaccinators.

In superintendence of local proceedings, my Lords during the year provided for the inspection of 1,651 vaccination-districts comprised in 336 different unions or parishes. The system, described in my last report, for awarding to meritorious public vaccinators certain payments in addition to those which are claimable by them from their respective boards of guardians—payments, namely, out of a special fund granted by Parliament for this purpose, had now come fully into operation: not indeed hitherto with the definite statutory sanction (30 & 31 Vict. c. 84) which at present regulates it, but with provisional authorization from the

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Treasury: and on this system my Lords during the year distributed 1,824*l.* among various vaccinators of England. The number of vaccinators to whom gratuities were given was 231; namely, 61 who received first-class, and 170 who received second-class, gratuities. The gratuities of each class differed of course very considerably in money-value in different vaccination-districts, just as the several contract-earnings differed. Where a public vaccinator was having so few vaccinations as to be only earning from his board of guardians some 20*s.* or 30*s.* a year, the supplementary payment by the Privy Council was necessarily quite insignificant as money, and, except that it implied an honorable recognition of services, might not have seemed worth the trouble of formal transmission and acknowledgment; but, on the other hand, in many cases the payments were such as probably to be in themselves welcome additions to the often scanty stipends of the recipients. The largest aggregate payment of the year (a second-class gratuity on 2,021 vaccinations) was 67*l.* 7*s.* 4*d.*; the smallest (a second-class gratuity on 23 vaccinations) was only 15*s.* 4*d.* It may be observed that if these had been first-class gratuities, as I hope they may be in future inspections, the respective amounts would have been 101*l.* 1*s.* and 1*l.* 3*s.*

My Lords during the year had occasion to correspond specially with the guardians of the unions of Tisbury, Sheppey, Dartford, Hendon and Lewisham, with regard to outbreaks of smallpox reported in those jurisdictions respectively; and in one of these cases (that of Sheppey) local inquiry by one of their Lordships' inspectors was made.

2. *Supply of Vaccine Lymph.*

Vaccine Lymph.

In answer to 13,240 applications made during the year for vaccine lymph, there were supplied under their Lordships' orders 131,480 charged ivory points, 2,460 charged squares of glass, and 8,167 charged capillary tubes. Particulars as to the sources whence this lymph was derived are given in Appendix No. 1. Of the 13,240 applications, in answer to which lymph was given, 10,434 came from medical practitioners (including 1,429 poor law medical officers) in England and Wales; 1,633 from Ireland, and 455 from Scotland; 428 from the army; 116 from the navy and emigration-department; 119 from colonies, and 55 from diplomatic and other foreign services.

My Lords, as usual, took means during the year to satisfy themselves as to the undiminished efficiency of the lymph which is supplied under their directions. The only change which took place in 1867 in regard of the London stations of the National Vaccine Establishment consisted in the appointment of Mr. W. E. G. Pearse to the Tottenham Court Chapel station in place of Mr. George Simpson, deceased.

3. *Educational Vaccinating Stations.*

Educational Stations.

Of the twenty-one stations which are sources of national lymph supply, thirteen are used as educational stations under their

Lordships' Order of December 1st, 1859, concerning the qualification of contractors for public vaccination. And Dr. Seaton, while inspecting these stations in reference to their stock of lymph, inspected them also in reference to their educational business. In this second respect, as in the former one, his report was entirely satisfactory.

III. Inquiries and Actions in other Matters.

Other Inquiries: occasional and systematic.

The proceedings of the Lords of the Council in 1867, in that general relation to the interests of the Public Health in which the Act of 1858 appoints their Lordships to stand, were, as usually, of two sorts. In the first place there were proceedings of an essentially *occasional* sort, with reference to particular outbreaks or threatenings of disease during the year, or to particular complaints which had been made of dangerous nuisance in various parts of the country; and in the second place, there were proceedings of an essentially *systematic* sort, forming part of a plan of work which goes on connectedly from year to year. And of these two sorts of proceedings the following were the main facts.

1. *Occasional Proceedings.*

Occasional Inquiries.

On numerous particular occasions where complaints of the state of districts were made, or where outbreaks of endemic disease had occurred or were apprehended, my Lords during the year had correspondence, which was for the most part with local authorities, with regard to the administration of the Nuisances Removal and other common sanitary Acts. The authorities thus corresponded with were 113; including the 76 nuisance authorities of Wales, 10 of the vestries and district boards of the metropolis, 10 boards under the Local Government Act, and 14 boards of guardians.

In three of these cases, namely, in regard of Winterton in Lincolnshire, Guildford in Surrey, and Terling in Essex, local inquiry by an Inspector under their Lordships' direction was deemed necessary: these being the chief cases in which in 1867 a prevalence of typhoid fever constituted the matter of complaint. All three cases were in substance such as I have again and again reported on, as illustrations of excremental poisoning; and this filthiest chapter in the history of our pestilences is one which I would gladly consider myself exonerated from re-opening on the present occasion. As regards those for whom primarily my Reports are written—the makers and administrators and officers of sanitary law in England, it may seem superfluous that I again proceed to illustrate in some detail the dependence of typhoid fever on conditions which it is disgusting to specifiy. But while the evil continues—while annually in England some fifteen to twenty thousand persons are killed, and perhaps twenty times that number grievously sickened and endangered, by a disease which solely prevails through the pollution of atmosphere and drinking-water with excrement, the subject

could not properly be set aside, unless Legislature and Government had already quite exhausted their powers in fruitless endeavours against the evil. I venture to believe that such is not the case; and purposing presently to invite judgment on this question, I shall briefly state here the leading facts of each of the three epidemics, and for further details append the reports of the inspectors who made the local investigations. See App. Nos. 2, 3, 4.

Typhoid fever in Winterton.

i. The little town of WINTERTON in Lincolnshire, having a population of about 1,800 persons, had for the last seven years been almost always suffering more or less from the presence of typhoid fever, and for the last two or three years the disease had been of great local importance. Sometimes it was more in one part of the town, sometimes more in another. In 1865-6 it particularly attacked a group of 35 houses at the west end of the town; and here, within the twelve months, out of 145 inhabitants 100 contracted the fever, and 17 died of it; or, in other words, those 145 inhabitants suffered in that year from the one preventable disease as many deaths as a population *seven times as great*, in fair sanitary circumstances, is expected to suffer *from all diseases and accidents put together*. Early in 1867 typhoid fever was again prevailing in large proportions in Winterton, but chiefly in another part of the town; and when their Lordships' inspector was there in April, there had been 55 new cases, and among them already 6 deaths. The cause of all this terrible sickness and mortality was of course evident to their Lordships' inspector at a glance. It was the merest question of filth. "The epidemic prevalence of fever in Winterton," he writes, "is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells. . . . . Given, the existence of typhoid fever in a town, it is hardly possible to conceive conditions more favourable for its spread than these existing at Winterton." Extracts which I append from his Report (App. No. 2) contain copious details in support of the above conclusion. The conditions described are such as probably even the swine in the town may have suffered from; and it deserves notice that the scene of this disgraceful sanitary neglect was a town which four years previously had adopted the Local Government Act.

Typhoid fever in Guildford.

ii. The epidemic of typhoid fever at GUILDFORD was peculiarly instructive. Guildford is not ordinarily quite exempt from typhoid fever; and during the first twenty-eight days of last August 10 such cases had been seen scattered about in the town; when suddenly within the next thirty-three days there had arisen fully 250 cases of the disease, and of this large number 150 had arisen within a fortnight. The distribution of the disease, especially during the first fortnight of the epidemic, so nearly corresponded in area with a particular section of the public water-supply of the town as to raise the strongest suspicions that this section of the water-supply was at fault. And eventually these suspicions became a certainty. First, namely, it was shown that on one particular day in August (about ten days before the beginning of the outbreak) 330 of the 1,675 houses of Guildford had

exceptionally received their water from a certain high-service reservoir which had been previously filled from a new well; and that the persons residing in or frequenting these 330 houses constituted the part of the population on which the epidemic influence had almost exclusively fallen. Subsequent chemical examination of the water of the new well detected in it the products of organic decomposition; and examination of the local circumstances showed, but too unquestionably, whence the decomposing organic matter had been derived. The new well, no one could doubt, was most dangerously situated: in the porous and fissured chalk-stratum, it was within ten feet of various sewers; one of which indeed was traversed, as a short cut, by the iron delivery-pipe of the high service. And when, after the epidemic, this reckless confusion of sewer and water-works was dissected, the state of things found at the spot, was reported to us in the following terms by Mr. Taylor, one of the Poor Law Medical Officers of the town:—"The engineers employed in the repairs of the steam engine noticed some exudation on the wall of the engine house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine house. The sewer was found leaking in various places, and the soil between it and the wall of the engine-house was saturated with sewage, of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain constructed with red unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark coloured fetid slush had to be dug out and removed in baskets, making the men vomit who were employed in the work."—There of course could not be any reasonable doubt but that the passage of this filth into the well, from which the high-service reservoir was filled, had been the cause of the epidemic. Mr. Taylor further informed us that the whole number of deaths from fever up to the end of the epidemic was 21, including three or four who died in other districts after removal from Guildford; and that he roughly computed the total number of cases of fever from August to December at 500.

Typhoid fever in Terling.

iii. The epidemic at TERLING, in Essex, was one of extraordinary dimensions. In that village of only 900 inhabitants, and for the most part within a period of two months, fully 300 persons were attacked with typhoid fever, and 41 of the number died. That is to say, the one preventable disease killed in that short time a larger proportion of the population than all causes of death put together ought to have killed there in two years. The conditions which rendered possible this most calamitous visitation of disease were, as in all our other experience, conditions of local filth. At Terling such conditions were at their worst. Round what pretends to be the house-accommodation of the tillers of the soil in Terling

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(a scanty overcrowded supply of dwellings of the meanest description) every possible source of pollution for air and water was accumulated; the peculiarly porous soil which underlay all this filth was of course continuously absorbing it; the water-supply of the population was derived from wells, most of them sunk in that excrement-sodden sponge of earth; some ten days before the outbreak of the fever, after an extraordinary period of drought, a sudden great rise in the water-level of the wells was observed; and this of course denoted a long-delayed scouring of that foulest soil into the water-supply of the now poisoned population. The epidemic incidentally deserved and received, for ulterior reasons, very particular scientific investigation; but my reference to it in this place is exclusively for practical purposes. The filth which did so enormous an injury to human life, existed under definite legal responsibility. The Nuisance Authority of the place (the Board of Guardians of the Witham Union) had most grossly neglected its duty. My Lords, in deference to what they believe to be the intentions of the Legislature, felt themselves bound to allow the Local Authority very ample opportunity even for tardy action; but when it became obvious to them that no sufficient use was being made of this opportunity, and that to spend further time in remonstrating with the Board of Guardians would not consist with due regard to human life in the district, their Lordships judged it necessary to move Mr. Secretary Hardy to put in force the compulsory provisions (Sections 16 and 49) of the Sanitary Act, 1866.

State of the law as to compensation of persons injured under the Nuisances Acts, &c.

I have already intimated that except for an immediate practical purpose I should not have thought it necessary again to give in one of my annual reports such extremely disgusting details as are here stated (partly in my last paragraphs, and still more fully in the appended reports of the inspectors) with regard to the local circumstances of our three chief fever-epidemics of 1867. But I have to raise a question which seems to me of the very utmost importance for the future sanitary progress of the country. And for the purpose of my argument I must refer to those three cases as types. They illustrate perfectly, but without any trace of exaggeration, the circumstances under which alone Typhoid Fever is empowered annually to kill so many thousands of our population, and to prostrate for months at a time so many scores of other thousands. Nor is this all. When cholera from time to time is among us, and its victims, during the short while of its prevalence, are counted in quick-succeeding thousands, like the slain and wounded of great battles, the circumstances of that pestilence are the same. The laws of its contagion in this country are substantially the laws of the fever-contagion: always there is the one story of filth: "excrement-sodden earth, excrement-reeking air, excrement-tainted water, these are for us the Causes of Cholera."* Now the point which I to some extent raised in my last report, as concerning the legal responsibilities of malfeasant water companies, is one to

* Ninth report, p. 33.

which I cannot but revert in connexion with our late Guildford experience: though now under slightly different circumstances, for on this particular occasion, as it happens, the water was purveyed by a local board. But the question which I am anxious now to raise is of very much larger scope than that formerly touched upon. It seems to me that the time has now come, when, not only as regards commercial water-companies, but also as regards local sanitary authorities, certain sorts of malfeasance should involve an obvious and unquestionable liability to pay pecuniary damages to persons whom the malfeasance has injured. I am not qualified to say that some liability to this effect may not at present be latent in our law: but I believe that at least it has never hitherto been judicially defined or affirmed: and it is evident that in this state of the case years may elapse before any aggrieved person, unless unusually rich and public-spirited, will be willing to incur considerable legal costs in testing his so doubtful claim to redress. I venture to submit that in this point of view the sanitary rights of the public are but very imperfectly secured, and that explicit legislation in the matter seems to me greatly to be desired. The effect of such legislation would be that what I may call *the fixed and finished parts* of sanitary science, as distinguished from those which are in any degree uncertain and speculative, would very rapidly become ordinary rules of conduct in civil life. In cases of alleged sanitary wrong, courts of law would have the facts in evidence before them; and judges and juries would determine whether wrong (in legal sense) had been done, and would assess the pecuniary damages in proportion. I would invite attention, in this point of view, to the three cases which are above reported. Apart from legal subtilties, on which I am not competent to speak, it seems that the distribution of fouled water by the Guildford Board (regarded for the moment as a water-company) is as proper a case for judge and jury, on action for damages by any of the 500 people who had typhoid fever in the town, as any case in which a railway-collision brings some scores of passengers into harm; and the fact (as I believe it to be) that these water purveyors gave typhoid fever to their customers would be brought home to their consciences, and be suggested as a warning to other water-purveyors, in a far more conclusive and effective manner by such legal proceedings as I suggest, than it can be by any departmental statistics and remonstrances. Again, as regards the epidemics at Winterton and Terling:—under 29 & 30 Vict., c. 90, sect. 20, it is expressly the duty of certain local authorities that they make from time to time (personally or by their officers) inspection of their districts, with a view to ascertain what nuisances exist calling for abatement, and that they enforce, in regard of such nuisances, the provisions of the Nuisance Removal Acts. If cases like those of Winterton and Terling were before a court of law, and the propositions were affirmed (as I apprehend they unquestionably must be) that the duty of the authority had been utterly neglected, and that the sufferings of the population, or of parts of the population, had resulted from the neglect, "injury," in that legal sense which implies a title to redress, would have been done by the

authority; and if hereupon each person who had suffered as above could recover his compensation from the rates, local authorities would immediately have the knowledge conveyed to them, in a far more practical form than it has yet assumed in their eyes, that sanitary neglect is a mistaken parsimony.

Apart from legal technicalities, on which I do not pretend to enter, the desiderata seem to me to be these three:—first, that for any purveyor of water wilfully or neglectfully to distribute foul water, or, where filtering is required, unfiltered water, and for any local authority to make default in such duties in relation to the public health as are by statute expressly imposed on it, should be (if they be not already) indictable offences, and that the production of disease by offences as aforesaid should be also (if it be not already) indictable; secondly, that it should be the province of some named central authority to take at its discretion legal proceedings against offenders as above; and, thirdly, that where such proceedings had led to conviction, all propositions affirmed in the verdict as to the causing of disease by the convicted person or authority at the time and place in question should afterwards be held proven for the purposes of whatever civil actions for damages might then be brought by private persons on account of injury sustained through the disease. It would of course in any action for damages be matter for question and proof whether the particular suffering had resulted wholly or in part from private fault, either in resistance to a local authority or otherwise; but looking to the spirit of our present nuisance-laws, especially to section 20 of the Act of 1866, I apprehend that nuisances on private premises could not *primâ facie* be deemed matters of solely private responsibility; and in regard of a large class of such cases, it may be doubtful whether an authority could quite exonerate itself of responsibility for the nuisances, even as against the owner of the premises, unless it showed that it had taken all proceedings required of it by law in such matters, or at least that the district possessed all proper facilities for the abatement of private nuisances. As regards such indictments as are above proposed, in which generally the indictment would be only for ulterior purposes, and the proceedings therefore only nominally penal, precedent exists in the indictability of parishes or other responsible parties for omissions to repair highways and bridges.

2.—*Systematic Proceedings.*

The continuation of the systematic work which was previously in progress in the department, with the object of increasing our exact knowledge of diseases, involved during 1867 some studies which were in the highest degree interesting and important. These studies were of two different sorts, which it will be convenient here to distinguish.

Systematic Inquiries.

i. *As to the Local Distribution of Disease, and the Circumstances by which it is regulated.*

I have to recall that in my last annual report a section to which I attached particular importance related to changes produced in the

public health in certain towns where of late years improvements in drainage and water-supply had been made. The largest result of the investigation then reported on (an investigation relating to 25 towns, with an aggregate population of 600,000 inhabitants was to show very strikingly the exemption which local populations obtain from cholera, typhoid fever, and other endemic bowel affections, in proportion as the local air and soil and water are kept free from excremental pollution: a result so confirmatory of much other evidence previously collected in regard of the same ætiological question, that henceforth apparently not even the most unwilling witness can deny the relation of cause and effect in that matter. But the inquiry had also some other results, of different degrees of value. And among such results one which stood in particular relief concerned the local distribution of PULMONARY PHTHISIS.

Relation of Phthisis to Dampness of Soil.

It was evident, namely, that in some of the towns which had been improved the mortality from Phthisis had notably diminished. And when detailed examination was made of the cases which gave that indication, in contrast with the different class where phthisis had not been lessened in amount, it appeared that the diminution or non-diminution of phthisis depended on whether the sanitary improvements of the place had, or had not, included any considerable drying of the soil. In cases where this condition had been fulfilled, the reduction of phthisis occured both too uniformly, and also in too great amount, to be regarded as of accidental coincidence. In a table then given, the reduction on previous phthisis-mortality, for the first 15 towns spoken of, was shown to be such as I now re-state in the adjoining table. And the fact that in some of the cases the diminished fatality of phthisis was by far the largest amendment, if not the only one, which had taken place in the local health, became extremely interestting and significant, when the circumstance was remembered that works of sewerage, by which the drying of soil is effected, must always of necessity precede, and do indeed sometimes precede by years, the accomplishment of other objects (house drainage, abolition of cesspools, and so forth) on which the cessation of various other diseases is dependent. Thus, as regards the two largest populations which were reported on—those of Bristol and Leicester, no doubt the comparative smallness of effect hitherto produced on the general and diarrhœal death-rates of those towns might (so far as it was not fallacious) be referred to the shortness of time for which finished constructions had been

The death-rates by PHTHISIS in the 15 undermentioned towns had, after improved land-drainage, fallen, *per centum* as follows :—

SALISBURY	49
ELY	47
RUGBY	43
BANBURY	41
WORTHING	36
LEICESTER	32
MACCLESFIELD	31
NEWPORT	32
CHELTENHAM	26
BRISTOL	22
DOVER	20
WARWICK	19
CROYDON	17
CARDIFF	17
MERTHYR	11

at work for the detailed dispollution of houses and their dependencies; but a reduction already of a sixth in the phthisis-mortality of Bristol, and a reduction already of a fourth in the phthisis-mortality of Leicester, were apparently connected with the fact that in both towns main sewerage on a large scale, with more or less drying of soil, had existed, in comparison, for many years. And Rugby, which, long as it had been at work, had not yet succeeded in getting rid of endemic diarrhœa and typhoid fever, showed at least this result of its main drainage works, that its phthisis-mortality had fallen 43 per cent.

The above facts, though not enough in themselves to prove as certain the very important ætiological relation which they suggested, were at least amply sufficient to show that a very promising line of inquiry had been opened. And my lords having on my representation been pleased to direct that this should be continued, Dr. Buchanan, the practised and skilful inspector who was engaged on the former general investigation, has now given me a further report of results obtained by him in a subsequent special research. That report (App. No. 5) is subjoined *in extensò*. It presents an elaborate examination of the distribution of phthisis, as compared with variations of soil, in the three south-eastern counties of England, beyond the limits of the metropolis; and it confirms, I think, beyond any possibility of question, the conclusion, previously suggested, that *dampness of soil is an important cause of phthisis to the population living upon the soil.*

This conclusion, so far as it rests on the above evidence, cannot, strictly speaking, claim to be proven for any other countries than our own; and a supposition might be advanced, though of course with little probability, that perhaps we had only succeeded in discovering an influence special to England. It is therefore with much interest that I am able to quote the result of an inquiry (which indeed was made long before our own, though it has only recently come to my knowledge) on the distribution of Phthisis in some of the United States of America. It appears that in 1862, in an address delivered at the annual meeting of the Massachusetts Medical Society, and afterwards published, Dr. Bowditch of Boston, U.S., drew attention, and not for the first time, to the remarkable inequality with which he had found phthisis to be distributed in Massachusetts, and, so far as he could ascertain, elsewhere in the States, and to the connexion of this inequality with differences of moisture of soil. He represented that "medical opinion in Massachusetts, as deduced from the written statements of resident physicians in 183 towns, tends strongly to prove, though perhaps not affording perfect proof of, the existence of a law in the development of consumption in Massachusetts, which law has for its central idea, that dampness of the soil of any township or locality is intimately connected, and probably as cause and effect, with the prevalence of consumption in that township or locality;" and he also adduced particular instances as tending to prove that even "some houses may become the foci of consumption, when others but slightly removed from them, but on a drier soil, almost

wholly escape."* It is moreover well worthy of notice that the Registrar-General of Scotland in his 7th Annual Report, adverting to Dr. Bowditch's work, has stated that, in his opinion, the mortuary statistics of phthisis in Scotland furnish evidence to the same general effect. With those corroborative statements in aid of the evidence which this department has collected, it must, I think, be deemed extremely probable that the influence of soil is universal. But at any rate as regards England, of which alone I have officially to speak, the conclusion as to the influence seems indisputable.

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In submitting this conclusion as one which, in my opinion, must henceforth stand among those scientific certainties on which the practice of preventive medicine has to rest, I take the opportunity of observing (though perhaps almost superfluously) that the conclusion does not purport to be more than a contribution to the ætiology of phthisis. That vastly fatal disease, if we are to have proper knowledge of its causes, must be studied from many different points of view. On former occasions (as particularly in my 4th and 6th annual reports) I have brought into relief the industrial relations of the disease, and now I insist on its occasional endemic relations. On those previous occasions it was shown to be a disease which undergoes development in proportion as men are *unwholesomely gathered in indoor industries:* now it is shown to be a disease which also develops itself in proportion as men are *dwelling upon a humid soil.* These two conclusions, no doubt, are very great ætiological fragments; but even when taken together they do not pretend to exhaust, or nearly to exhaust, the subject of the causation of phthisis. Thus, it may suffice me in passing to note that our studies of the disease have not yet touched its immensely important *hereditary relations.* And even in the present volume I shall directly have to bring under consideration another and entirely different aspect of the disease—that, namely, in which its intimate pathological affinities have to be discussed, and the *nature of the morbid process* which establishes it. That in both those directions the acquisition of further knowledge may very greatly increase our power of preventing a disease which now causes in England probably at least an eighth part of the entire mortality, will not, I think, seem improbable to anyone who well considers the subject; but meanwhile I may point with great satisfaction to the eminently practical character of the conclusions already obtained. Phthisis, so far as it depends on unwholesome circumstances of indoor industry, has, since my former reports, been made preventable under the law;†

Causes and Preventability of Phthisis.

* My quotations of Dr. Bowditch's work are from a second edition, which has quite recently been published in America:—"*Consumption in New England and elsewhere, or Soil-Moisture one of its chief causes;*" Boston, 1868. We here, as Dr. Buchanan states, had been entirely unable to obtain a copy of the original work; and the copy of the re-issue, which I owe to Dr. Bowditch's kindness, has reached me only since the completion of Dr. Buchanan's report.

† See Factory Acts of 1864–7, Work-places Regulation Act of 1867, and section 19 of the Sanitary Act, 1867.

and phthisis, so far as it depends on wetness of soil, may easily in great part be made similarly preventable.

Distinction must, of course, here be drawn between populous and non-populous places. An undrained state of soil in any place where population is aggregated answers to the legal intention of the word "nuisance;" and I apprehend that, even in the present state of the law, the local sewer-authority is bound to provide that such a state shall not continue through want of proper constructions for the drainage. For agricultural lands, no doubt, the case is different. It may not be practicable to require that such lands, though damp enough to cause phthisis to the comparatively few and scattered persons who reside on them, shall be artificially drained by their owners; and the interests of agriculture in this respect are not always identical with those of human salubrity. But at least the law might unequivocally condemn, so far as detrimental to health, all damming of natural drainage. And for river-conservancies it would be a function, scarcely if at all less important than that of preventing the pollution of rivers, that they should also, as far as possible, prevent or remedy all such artificial and natural obstructions of water-flow as keep tracts of inhabited land sodden with stagnant wetness.

ii. *Particular Processes of Disease investigated in scientific Detail*

Investigation of Processes of Disease.

A very important branch of the systematic work of the department is represented for 1867 by the last two papers of my subjoined appendix, Nos. 6 and 7, by Dr. Sanderson and Dr. Thudichum respectively. In my eighth report (pp. 20–1) I have stated the circumstances under which my Lords, early in 1865, determined that in future there should to a limited extent be conducted under their auspices such investigations in abstract pathology as might seem likeliest to be of ulterior effect in the more immediately practical and popular objects of this Department. The present is a time of the most extraordinary transition and progress in the sciences which are fundamental to medicine; so much so, that scarcely a month passes without raising some new pathological question which bears upon principles of action; and this Department, practically considered, would be lagging far behind the knowledge which ought to be represented in its administration, and might often be spreading mere obsolete error among persons who look to it for intelligence, if it were not itself able to submit such questions to examination, and thus and in other ways to take part in the scientific reconstruction which is in progress. The application of work of this description is, as I need hardly observe, in the first instance exclusively technical: the work addressing itself primarily to certain scientific requirements of the medical profession, and not pretending to be applicable to popular uses so immediately as the other work of the department: and, in this state of the case, it is not necessary that I should here enter, except briefly, into a discussion of the subject-matter of last year's investigations. Some short explanation, however, may be convenient.

Inoculability of Tubercle.

a. Dr. Sanderson's report relates to the process by which so-called *Tubercular Disease* is established in the animal body—such disease as, for one of its forms, is illustrated in Pulmonary Phthisis, and which, in that and other forms, is among the most fearful scourges of human life in this country. The morbid process, terribly frequent as it is, has not yet come to be well understood. Of its chemistry (which may probably hereafter prove to be the true criterion of its nature) absolutely nothing is yet known. Of the way in which its best recognized external causes become capable of engendering it in the human body, we can scarcely be said to have a conjecture. And even of its anatomy (though this of late years has been more successfully investigated) the facts are not yet nearly complete. On the other hand, its relation to some other diseases had long seemed, in a very general sense, to be tolerably sure: it had been assumed for instance—and the assumptions are represented in our commonly received classifications of disease, first, that the process must consist in "specific," as opposed to "common inflammatory," local changes; and then that the root of these changes must be something so inherent in the original nature of the sufferer, and so independent of any contagious influence, as to make tubercle the type of so-called "constitutional" diseases, in distinction from all extrinsic, and particularly from all "zymotic," diseases: but even while these assumptions were not openly contested, considerations were accumulating which caused every cautious pathologist to speak with great reserve on the subject. In this state of the case, suddenly, some two and a quarter years ago a very startling discovery was announced. Dr. Villemin, of the Val de Grâce Hospital in Paris, on the strength of a large number of experiments which he had performed on some of the lower animals, claimed to have established that tubercle is inoculable from subject to subject, and is in fact as "zymotic" as syphilis. Various observers (among whom I was one) were soon able to satisfy themselves that M. Villemin's descriptions were entirely true for the field within which he had experimented; but it was evident that no general view could properly be based on results such as his, till the answers to many other questions should have been brought within the field of study; and as the line of inquiry which he had opened would at any rate almost certainly involve immense pathological consequences, the more comprehensive research was peculiarly to be desired. My Lords, early last year, were pleased to authorize that such a research should be undertaken on a large scale in this department. One great portion of the consequent work is represented in Dr. Sanderson's present report, and other portions of it (with a view to my next annual volume) have already been committed to him for completion. The results which have hitherto been reached are not in an unqualified sense final; but even this first stage of the inquiry, besides leading as it does to ulterior questions of the utmost interest, has already given us definite and important knowledge.

The conclusions to which hitherto we have come may be stated as follows. First, M. Villemin's fact is established as unquestionable:

certain of the lower animals, if inoculated from the human subject with the morbid products which are called "tubercular," will in consequence develop, more or less extensively throughout their bodies, a disease, which, so far as present criteria can decide, is identical or nearly identical with the so-called "tubercular" disease of man; and from this fact, taken with previous knowledge as to the mode in which "tubercle" in man tends to spread infectively from its original site to secondary and tertiary sites in the affected body, it would at first seem that human "tubercle" must be a specific zymotic disease. Against this, however, the correction has to be applied, that, in the rodent animals on which hitherto an immense majority of the inoculative experiments have been performed, a disease, which, if it were in the human subject, we should unhesitatingly call "tubercle," may certainly and (it seems) very easily arise in continuation of "common inflammatory" phenomena; that not only the "tubercular" inoculation from man, but other morbid inoculations, and even "common" local lesions, may be followed by diffuse tuberculisation of the rodent's body; that, for instance, a slight open wound, such as that of a seton run beneath the skin, is not, as in man, an affair of simple irritation which ceases when the irritant is withdrawn, but is capable of being the first step in a series of changes which gradually infect the creature's whole body with imitations of the human "tubercular diathesis," and thus at last create such "tubercular" disorganizations as necessarily destroy life.

Here, for the present, we stop, and it would be idle to conjecture what further knowledge may hereafter be gained in this very instructive line of inquiry. I may venture, however, to point out that some of the present observations, in converse as it were to their first teaching, prompt a curious second reflexion. They suggest, namely, a speculation with regard to human "tubercle," such as may indeed extend to many human diseases which are called specific and zymotic, whether perhaps our pathological terms "common" and "specific" may not, more than has yet been supposed, be found variable with the particular animal spoken of as affected, rather than attaching fixedly to the given diseases; whether, namely, the "common inflammatory" affections of some animals may not be the "specific" affections of others; whether, for instance, some "common" traumatic affection of this brute or that may not correspond in essential chemistry to this or that "specific" zymosis of man, and even in some cases be the source whence the latter was first derived. Of course no speculation of this sort can be conclusively argued till our present imperfect scientific definitions of morbid processes shall have been very greatly improved.

Chemical Researches.

b. Dr. Thudichum's report, even in some respects more than Dr. Sanderson's, represents only part of an unfinished work of the department: but here the projected work is so large and heterogeneous that of necessity its separate sections must often be regarded as wholes. The scope of the entire work is an

endeavour which my Lords are making in this department to contribute towards the establishment of precise knowledge in those chemical aspects of pathology where at present there is almost utter darkness. It is only among persons who are fairly conversant with the present difficulties of the medical sciences that the full obstructiveness of that defect can be measured. It means, alas, that very large parts of practical medicine, both preventive and curative, are even yet in a state of grievous imperfection. Both within and without the profession, certain general words which have become current are apt to convey erroneous impressions on that subject. With our various infectious "fevers," for instance: —we state that they have, as their common and probably essential character, an extraordinary development of contagious chemical activity (or, as we call it, "fermentation" or "zymosis") in the affected body; but behind these general words there is so little exact knowledge, that we have not the remotest conception wherein the "chemical activity" of smallpox differs from that of scarlatina or of typhus, or what is the chemical difference between their respective fevers and the fever of a broken leg or skull. Similarly with our so-called "dyscrasies": — we are ready to tabulate together under that old Greek word a large number of diseases of which we think we know that they represent habitual indolence, or other chronic misbehaviour, in the chemical working of the body or of certain organs—such habits of body as the gouty, the scrofulous, the rheumatic: but not of one of these dyscrasies, not even of the most studied of the number, are we yet able to give any description which a chemist would recognize as intelligible. And this, be it observed, is in regard of diseases which by common consent are either primarily, or in a high secondary sense, chemical. Of course a third group might be cited of other diseases, which also (like the above) present very prominent chemical phenomena, but which hitherto are so imperfectly known in this point of view that we hesitate whether to call them dyscrasies or not: such diseases as cancer, rickets. Here in short is a large number of our most important diseases, for which hitherto we have not even approximately got proper pathological definitions. And the evil of this is not only that in our purely scientific discussions we are again and again brought to a standstill by the embarrassment of undefined terms;* but also the defect which I describe lies at the very root of what is now least satisfactory in our practice. What we want in respect of our morbid processes, so far as they concern the chemistry of the body, is to be able to define them in precise chemical language: to be able, for instance, as regards any disease which is rightly considered

* For instance, some two years ago, when the cattle-plague began to be much talked about here, public discussion arose whether the disease was of such nature that it ought to be called bovine smallpox; but this discussion was (I may venture to affirm) simply futile, as no one could define "smallpox" in any sense which would supply a reasonable standard for the comparison. And the same sort of thing is illustrated to some extent in what I have written in the preceding section as to the communicability of "tubercle." For, what is tubercle?

zymotic, to say that the bodily materials which it specifically affects are such and such, and that in the disease these materials pass through such and such stages of transformation, ending in such and such results: and to be able to express all this in as exact chemical terms as we apply to vinous or butyric fermentation. Failing this, we have no final pathology of such cases as are in question; nor is it likely that we should have for them, except by accident, any radical treatment or prevention. No doubt there may be lucky successes, as where we inherit specific antidotes or half-antidotes, more or less uncertain, for gout, or syphilis, or ague; and there are the many far different successes, where the skilful practitioner with treatment which is confessedly but provisional and palliative (though not on that account the less scientific) avails himself to the utmost of present symptomatological knowledge, and watchfully resists disease in the detail of each special influence by which it proximately tends to shorten life. But the total of these various successes leaves still much unsuccess to be deplored; and probably those who are most efficient in administering the present resources of medicine would be of all persons the most conscious how limited in some directions, and specially in such as I am now considering, are the resources which are yet at their command. And evidently for future progress, the possibilities of medicine are but two: on the one hand we have the chance, such as it is, that from time to time new specific antidotes may accidentally be discovered; on the other hand, there is the power of deliberate scientific discovery and application. The latter, in regard of such chemical diseases as are here under notice, must presumably, in some or all of the most important stages of its development, be a question of purely chemical work; and it would, I think, be unwise to assume in respect of any such chemical case, that the ends of preventive and curative medicine can be reached till our practical proceedings shall have got to be demonstrably based on the very chemical formula of the morbid process.

There is here of course no intention to depreciate in even the smallest degree the services which other kinds of observation and experiment as to the forms and forces of health and disease may render, and have rendered, to medicine. Every step in the physiological sciences, every better knowledge of the organs of the living body, and of their material and functional fluctuations under whatever influences, is of actual or potential gain to us; and such knowledge, even where it sometimes tends but little to the final interpretation of disease, constantly gives more and more success to the provisional practice which it enlightens. As regards the anatomical studies of late times, with the very advanced utilisation of the microscope, and the otherwise greatly improved means of minute structural investigation, I need hardly say that, by them, during the last thirty years, great parts of the science of disease have been completely transfigured, and that even now from year to year this mode of inquiry continues to give most valuable results. How much importance is attached to it in this department is indeed illustrated in the present volume by the minuteness of

anatomical research with which Dr. Sanderson's report is written. But one of the best lessons which any science can teach us is enabling us to see what are the necessary limits of its own teaching-power; and thus by help of the microscope we have come to learn, in respect of a vast number of the most important problems of pathology, that what it can teach is only generic, while what we want to know is special, that diseases practically most dissimilar may be indistinguishable in ultimate anatomy, that our few simple types of structural change are but vague and most imperfect symbols of the innumerable chemical changes which they embody. Nor, as regards the zymotic diseases, do I undervalue the great scientific interest of such investigations as I last year quoted from Prof. Hallier in respect of cholera, and might now quote from him in respect of several other such diseases, as tending, in his belief, to establish that micro-fungi of various sorts constitute zymotic contagia; but, however great may be the future development of such investigations as those, and however unquestionable their results, the field in which such knowledge might prove applicable is one where in most instances the interest of the microscopic ferment would be practically as inseparable from the chemical study of the disease, as the interest of the yeast-plant is inseparable from the study of the decompositions amid which it lives.

The above, in substance, are views which I have for many years entertained and expressed as to the very great need of chemical research in aid of such practical objects as those with which this department is charged: but till very recently such researches could not have had much promise of success: and it was only three years ago that I felt justified in asking my Lords to allow me special assistance for an attempt to lessen the defects of which I complain.

Of the work which since then has been done for the Department by Dr. Thudichum, part was represented in my last year's volume by a report on the chemistry of cholera, and another considerable part is now represented in my subjoined Appendix, No. 7. The medical reader will see, without surprise, that a large proportion of the present work is of a kind which may almost be called preliminary; partly that it deals with those sections of physiological chemistry with which our great patho-chemical problems are most nearly related, and in which, essentially for our purpose, very exact standards of healthy chemical process have to be ascertained; and partly that much study is given to artificial and post-mortem processes which in some degree resemble processes of disease. The more direct researches have brought into strong light (as may particularly be seen in section 3 of the Report) the necessity which caused that course to be taken. The present researches, besides investigations of particular morbid phenomena, have chiefly related to the decompositions of albuminous substances, to the colored corpuscles of the blood, and to the coloured ingredients of bile and urine. It has been found convenient to

prefix to the account of these researches a compendious introductory view of the present state of the case to which the researches apply; or (as the title of the section runs) a "sketch of chemical physiology, and of its points of contact with pathology." Further, the spectroscope has proved so essential an instrument of investigation as to require particular notice in the report; and, therefore, the information given as to the spectroscopy of the blood is preceded by some general information as to the construction and uses of the instrument. Also the report has a supplementary section on alcohol and its relations to the human body; particularly in settlement of the much-debated medical question whether alcoholic drinks contribute to nourish the body into which they are taken.

JOHN SIMON.

APPENDIX.

No. 1.—Statistics of the National Vaccine Establishment.

1. Staff of the Establishment at end of 1867.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the purposes of their Lordships' Order of December 1, 1859.

—	Members of the National Vaccine Establishment supplying Lymph for the Public Service.	Vaccinating Stations.	Days and Hours of Attendance.
Vaccinators salaried from the Parliamentary Grant.	Mr. John Newton Tomkins, Inspector.	Fitzroy Street.	Mon., Tues., Wed., Thur., Fri., Sat.; 10—11.
	Mr. James Furness Marson.	*Surrey Chapel, Blackfriars Road.*	Tuesday, Thursday; 1—2.
	Mr. George Lewis Cooper.	Battle Bridge.	Tuesday; 12—1.
	Dr. Richard Sharpe -	Bermondsey.	Tuesday; 10—11.
	Mr. Robert Wade -	Dean Street, Soho.	Monday; 9—11.
	Mr. Arthur Bernard Macann.	King Street, Portman Square.	Monday; 10—11.
	Mr. Wm. Jones Lewis.	Spital Square, *Wellclose Square.*	Monday; 10—11. Tuesday; 9—11.
	Mr. W. E. Grindley Pearse.	*Tottenham Court Chapel.*	Monday, Wednesday; 1—2.
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	Mr. Ellis Southern Guest.	*Manchester.*	Monday; 2—4.
	Mr. John Garner -	*Birmingham.*	Monday; 10—12.
	Mr. William Yeoman Sheppard.	*Bristol.*	Tuesday; 11—12.
	Mr. Arthur Browne Steele - -	*Liverpool.*	Monday; 9. Friday; 2.
	Mr. John Henry Wilson - -		
	Mr. John Fenton -		
	Dr. Edward Lowe Webb.	*Pimlico.*	Monday; 10—12.
	Mr. George Cuthbert Gilchrist.	*Newcastle-on-Tyne.*	Tuesday; 2—3.
	Mr. William E. Grindley Pearse -	*Westminster.*	Monday; 9—11.
	Mr. James George Gerrans.	*Marylebone.*	Monday; 10—11.
	Mr. Frederick Holmes	*Leeds.*	Tuesday; 3¼.
	Dr. Edward Lynes -	Coventry.	Monday; 12—2.
	Mr. Joseph Teale -	Salford.	Thursday; 2½.
	Dr. James Dunlop -	*Glasgow.*	Monday; 12—1.

APPENDIX.

No. 1.
Statistics of the National Vaccine Establishment.

Statistics of the National Vaccine Establishment—*continued.*

2. SOURCES and AMOUNT of LYMPH SUPPLY in 1867.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the Purposes of their Lordships' Order of December 1, 1859.

—	Vaccinating Stations.	No. of Vaccinations performed at the Stations respectively.		No. of charges of Lymph supplied from the Stations respectively.	Remarks.
		Prim^y	Re-vac^ns		
Vaccinators salaried from the Parliamentary Grant.	1. Fitzroy Street	478	—	5,200	
	2. *Surrey Chapel*	968	52	14,100	
	3. Battle Bridge	474	—	5,294	
	4. Bermondsey	534	61	7,696	
	5. Dean Street, Soho	421	24	10,080	
	6. King Street, Portman Square	257	12	4,556	
	7. Spital Square	276	—	10,992	
	8. *Tottenham Court Chapel*	1,506	58	13,756	
	9. *Wellclose Square*	244	—	9,678	
Total	9 Stations	5,158	207	81,272	
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	1. *Manchester*	1,334	7	17,640	
	2. *Birmingham*	1,157	54	5,583	
	3. *Bristol*	252	—	1,600	
	4. *Liverpool*	919	7	16,287	
	5. *Pimlico*	870	106	34,975	
	6. *Newcastle-on-Tyne*	383	26	8,265	
	7. *Westminster*	784	18	15,602	
	8. *Marylebone*	1,073	153	10,724	
	9. *Leeds*	464	6	8,257	
	10. Coventry	464	—	1,660	
	11. Salford	755	—	7,212	
	12. *Glasgow*	714	—	7,560	
Total	12 Stations	9,169	377	135,365	
General Total	21 Stations	14,327	584	216,637	

Statistics of the National Vaccine Establishment—*continued.*

3. SUMMARY for the Years 1856–1867.

Year.	Total Vaccinations performed at the Stations which supply Lymph.	Re-vaccinations included in preceding Column.	Number of Charges of Lymph supplied.
1856 - -	7,039	?	210,942
1857 - -	6,327	?	213,207
1858 - -	6,445	?	234,150
1859 - -	9,030	?	237,801
1860 - -	13,849	?	228,347
1861 - -	12,009	?	225,000
1862 - -	13,149	?	211,475
1863 - -	20,600	?	239,432
1864 - -	13,727	?	203,250
1865 - -	14,648	515	219,832
1866 - -	14,319	372	207,014
1867 - -	14,911	584	216,637

APPENDIX.

No. 2.
On Epidemic Typhoid Fever at Winterton, by Dr. Thorne.

No. 2.—EXTRACTS from REPORT by Dr. R. THORNE THORNE on EPIDEMIC TYPHOID FEVER at WINTERTON.

* * * * *

Winterton is a small market town, situated on a gentle slope, in the northern part of the county of Lincoln, about two miles south of the Humber. It consists mainly of one street, called the High Street, running directly from east to west, but at the western extremity houses are also collected around an open space originally occupied by a pond, and round two sides of the churchyard. The town, which is on high ground, is situated on a stratum of oolitic limestone, which is very porous, and easily admits of the percolation of fluids. Above this substratum lies a clay marly soil.

In 1861 the population was 1,780, and since that date it has, for two reasons, not increased beyond about 1,800. The first of these is the establishment of ironworks at a neighbouring village, where many of the inhabitants now find employment, and where they have, in consequence, settled. The second and more important reason is, that until the Union Chargeability Act was passed, the nobility in the adjoining parishes refused to allow of any cottage property or of paupers on their estates, and Winterton being a freehold town, the labourers who worked the land for a circuit of nearly four miles around, all took up their abode there. Recently, however, the paupers being maintained out of the general union rate, instead of the parish rates, the landowners have commenced to build cottages on their own property, where their labourers now reside.

The town is under the government of a local board, the only other officials being the clerk to the board, and a labouring man who holds the appointments of town surveyor and inspector of nuisances. Its situation on a slope gives great natural advantages to Winterton as regards sewage, and within the last few years a very effectual main drainage has been laid through the town. Into this drain a running stream has been diverted, and thus a continual flow of water is kept up nearly throughout its whole length. Two outfalls carry the drainage into a brook running parallel with, and outside the town; this discharges itself into an artificial piece of water called Sir Rowland's Drain, which in its turn runs directly northwards, and joins the Ancholme river, just before this stream empties itself into the Humber. All the openings from the street gutters into the drain are well constructed and properly trapped, and with the exception of one of the outfalls which have just been mentioned, and to which reference will again be made,* the whole system works efficiently. The town consists almost entirely of cottages, which are, with few exceptions, well built, of brick or of limestone. Absolute poverty is but little known there, for though about nine-tenths of the population consist of the labouring classes, yet these, when in health, almost all earn good wages; intemperance, also, is rare, so that neither of these causes can be said to be at work in predisposing the inhabitants to disease. Ague was up to 30 years ago very prevalent in the district, but since the neighbourhood has been properly drained no cases have occurred.

The mortality of the town for the last 10 years has been as follows:—

For the year	1857	34 deaths
„	1858	47 „
„	1859	42 „
„	1860	33 „
	1861	37 „
	1862	32 „
	[illegible]	31 „

For the year 1864	- - -	59 deaths
„ 1865	- - -	51 „
„ 1866	- - -	44 „

The increase in 1864 was mainly due, I am informed, by the union medical officer, Mr. Bennett, to an epidemic of scarlet fever, and since then to the prevalence of the fever which has been the cause of this inquiry.

Winterton is at present suffering from a widely spread epidemic of typhoid fever. This disease, according to Mr. Bennett, has never been entirely absent from the town for nearly seven years, but during the last two or three years only has it affected so large a number of the population as to give rise to public anxiety. The epidemic is now *principally* confined to the east end of the town, where it has attacked the poorest class of the inhabitants, but during the past year almost all the cases occurred at the west end, in the houses adjoining the churchyard. These houses are 35 in number, and Mr. Bennett's books show that from June 1865 to June 1866, out of 145 persons residing in them 100 suffered from fever, of whom 17 died. The upper classes and the tradesmen have not been exempt from the fever, but at the time of my visit none but the labouring classes were suffering from it.

From Mr. Bennett's position as union medical officer, almost all these patients are under his care, and by his permission I visited with him all those who were now under treatment. The number I thus saw was 49, all of whom exhibited the various symptoms of typhoid fever, including the rash and the bowel affection, with the exception of a few whose cases were of too recent a date for the eruption to have exhibited itself, and a few more who were progressing towards convalescence, but who had evidently suffered from some acute febrile disease. In addition to these cases there were six under Mr. Sadler's treatment, making a total of 55 cases. Notwithstanding this large number, the mortality has been small, six cases only having terminated fatally since the 1st of January this year. This is to be accounted for by the fact that at the present time the disease is in by far the majority of instances of a mild type; indeed I saw several patients sitting up, who had well-marked rose spots about them, and were suffering from diarrhœa at the time of my visit.

The epidemic prevalence of fever in Winterton is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells. With the exception of about six houses, where waterclosets have been constructed, all the cottages are provided with privies, which are generally built of brick, and have an aperture at the side or back, through which they can be cleaned out. This aperture I found open in almost all instances, and the result of this is that the contents of at least half the privies in the town run out into the gardens, soak into the earth, and penetrate in many instances into the wells, besides producing the most offensive odour. In addition to this many of the tenants either throw their refuse and slops, including urine, into the yards outside their doors, or else they improvise a receptacle by digging in the ground close to the aperture in the privy wall. The fæcal matter pours into it, and they thus add to their previous list of nuisances that of an open cesspool. In some instances ashpits have been built, but these are uncovered, and since urine and the bowel discharges of the typhoid patients are thrown into them, in addition to other refuse, they are but little better than open privies. All these sources of fæcal fermentation are situated as a rule close to the houses, and in some instances within a few feet of the back doors, and just under the windows. The wells are also in their immediate neighbourhood, and many of the inhabitants informed me that their water was so bad that they had been compelled to discontinue drinking

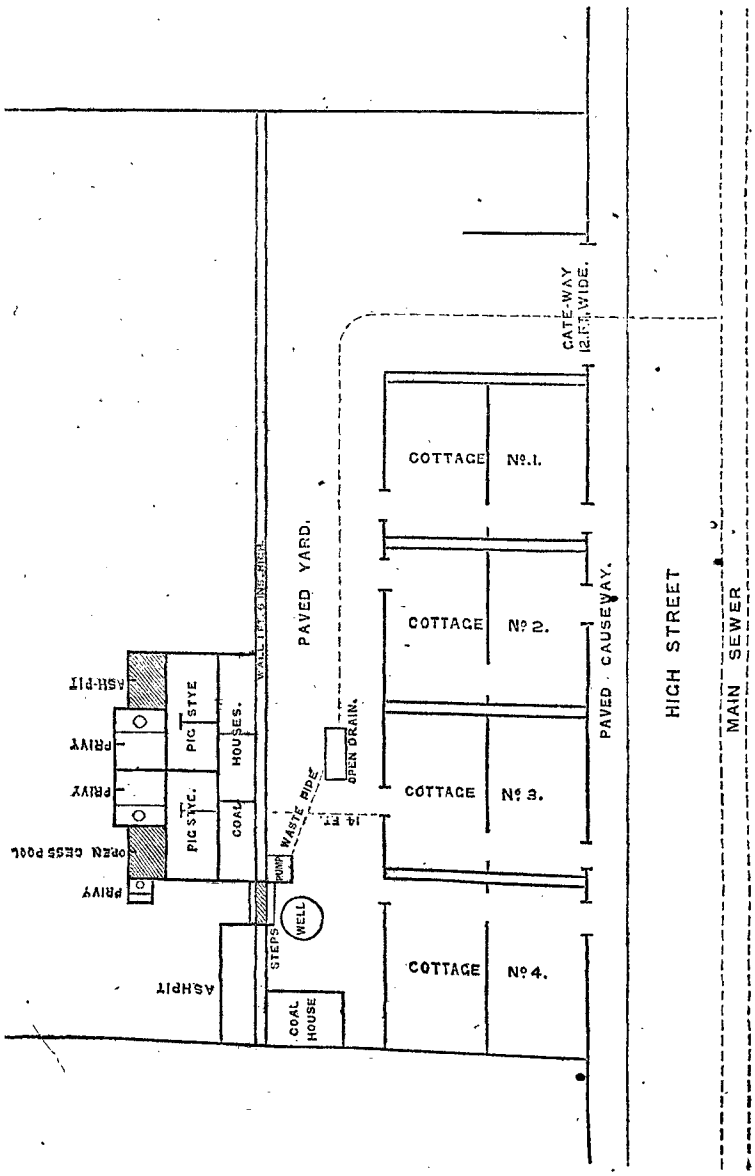
APPENDIX.

No. 2.
On Epidemic Typhoid Fever at Winterton, by Dr. Thorne.

it. In one instance I found the space between two pigstyes entirely occupied by a well 3 feet in diameter. Fever is present in the house to which this well is attached, but since the occupants do not use it, the necessarily contaminated condition of the water cannot be considered to bear upon the disease. Given, the existence of typhoid fever in a town, it is hardly possible to conceive of conditions more favorable for its spread than those existing in Winterton.

The record of a few cases differing in no essential points from all those I visited, will exhibit something of the evidence on which this statement is based.

A group of four cottages, the property of Mr. Dale of Appelby stand in the High Street; their back doors all opening into one common yard



14 feet wide (*vide* diag.) In front of the third house and within 5 feet of the windows is an open untrapped drain, which communicates with the main sewer, but owing to this communication being defective a large quantity of stinking fluid which partly consists of urine, has accumulated there. Within 8 feet of this is the pump, from which a waste pipe runs into the drain; but when the drain does not properly empty itself, that is to say, when it is in the condition in which I found it, the fluid regurgitates up towards the pump. The well which supplies all these four cottages with water lies 2 feet to the west of the pump, at the foot of two steps leading into the gardens behind the cottages; these gardens being raised above the yard, and sloping towards it. Close by these steps and overhanging the well, is an open ashpit, on which the bowel discharges of typhoid patients are thrown, in addition to filth and almost every description of decomposing matter, which it is possible to conceive. A few feet higher up the garden, and within 6 or 7 feet of the well are two pigstyes. Immediately behind these, and raised slightly above them, are three privies, and one cesspool; two of the former are filled with night soil nearly up to the seats, the remaining one is less full because it empties itself into the open cesspool. The pestilential odour in the neighbourhood of this group of nuisances it would be almost impossible to describe; suffice it to say, that on pointing them out to the inspector of nuisances, that official, as on several other occasions, politely begged to be excused from approaching them any nearer. In short we have within a circuit of about 14 feet round this well one open drain, one open ashpit, two pigstyes, three privies, and one open cesspool, all of which with the exception of the drain, are raised to a height varying from 1 foot 6 to 3 feet above it, and situated on a loose porous soil.

As a result of this I found that in cottage No. 1, where three persons live, two have had fever, of whom I saw one, viz. Joseph Hewson, a labourer, who was evidently recovering from some acute febrile affection. No. 2 was empty, but I ascertained that up to eight weeks ago, four persons resided there. The neighbours told me that "they were always ill," and Mr. Bennet stated that one of them had died of fever. No. 3. Here seven persons live, all of whom have had fever. In this house I found in a small room 12 feet × 8 feet and 7 feet high, Henry Driffell, bricklayer, ætat 32, lying in a semi-comatose condition, on a mattress saturated with urine and fœcal matter, to such an extent that the ammoniacal and fœcal emanations were absolutely pungent, and I was compelled to go to the window which I found closed, and open it, in order to breathe some fresh air. Covering the patient were a blanket and a sheet, also saturated with his discharges. The nurse, who had been provided by the parish, was so exhausted from continually watching him day and night, that she was no longer able to move him, and if she had been, she stated that it would be useless, as she could obtain for him no change of linen. . . . . In another room lay this man's wife, who was also attended by the same nurse. In No. 4 four persons live. I examined them, and found them all free from disease. They informed me that they had never been ill.

On continuing my inquiry I ascertained that the inmates of cottages Nos. 1, 2, and 3, where the epidemic has been so rife, all of them drink the water from the well just described; those living in No. 4 and who have always enjoyed good health, not liking the taste of it, have drawn their water from a neighbour's well.

Nothing could point much more conclusively to the contaminated state of this water, and on examining it I found it to be of a light brown

colour, and disagreeable taste, and to yield a considerable deposit after standing for a few hours. Under the microscope it exhibits a large quantity of organic matter, both animal and vegetable, as well as infusoria and animals of a low type (*vide* diag.)

As a second example I will draw attention to a house situated also in the High Street, the property of Mr. Dent, M.P., and occupied by William Backhouse and his family, in all four in number. I there saw Alice Backhouse ætat. 4, who had been attended by Mr. Bennett for "fever," which from the symptoms enumerated including diarrhœa and hœmorrhage from the bowels, was evidently of the typhoid type. The patient had recovered from the acute stage, but was frightfully emaciated, had abscesses over the tibiæ, and several bedsores, as the remote effects of the disease. In the house itself I found the chamber utensils containing fæces and urine although my visit was made at about midday. Thirteen feet from the door is an open ashpit on which some of the fæcal discharges of the patient named had been thrown, and where they still lay uncovered. By the side of this is an open drain. At a distance of about 30 feet from the house is the opening from the main drainage into the second outfall to which I have referred above (*vide* page 28). Close by stands the privy used by Backhouse and his family. This privy is built on the edge of the outfall, and by an aperture in one of its walls it empties itself into it. The outfall is merely an open ditch, the contents of which, contaminated as they must be by the typhoid discharges from the privy, I found spread out on the tenant's garden, this proceeding having been ordered by the town authorities for the purpose of cleaning it out. The stench just around this outfall, privy, and ashpit was worse than anything I found in the whole town. The water on these premises was never used for drinking purposes on account of its bad taste, and therefore it cannot have had any influence in causing the disease. I examined the premises from which they borrowed water, but was unable to detect any source of contamination.

One other set of cottages, two in number belonging to a gentleman named Fowler, will furnish me with my last example, and I refer to these particularly because they afford the only instances of overcrowding with which I met.

Both these cottages are again situated in the High Street, and the first is occupied by a family of nine persons named Altoft. Among them five cases of fever have occurred, one of which has proved fatal. On examining the interior of the house I found that nine persons slept in one room, of which the window was habitually closed, and the fireplace blocked up with bricks and cement. I took a measurement of the room and thus ascertained that each individual had less than 160 cubic feet of air. The privy outside was full to within 6 inches of the seat, stale urine covered the floor, and the soil was exuding through the brickwork at the back and escaping into the garden. There being no ashpit either to this cottage or the next one, all the slops, including urine, are thrown into a yard behind, and within a few feet of the doors

I found strewed indiscriminately, ashes, straw, fish, and vegetables undergoing decomposition. The next cottage is inhabited by six persons named Hill, five of whom have suffered from typhoid fever; one of these I saw with all the characteristic symptoms. He lay in a room 8 feet × 6 feet; this he shared with two others, each person only having 96 cubic feet of air. In addition to this, the room which is on a level with the street has a damp brick floor, and no window or fireplace, the former having been blown away by a gale some months ago, and not being replaced the tenant has been compelled to board the opening up. Thus neither light nor air can penetrate the room. The privy adjoining this cottage is so full that its contents rise literally above the seat, and I was informed that it had been in this state for six months; the inmates are thus compelled to resort to the one belonging to Altoft's cottage, which on this account is used by 15 persons.

The cases enumerated are fair examples of what I found throughout the whole town. In some instances I endeavoured to ascertain whether the fever could have had a spontaneous origin, but the inhabitants all seem to be on such terms of intimacy with each other that they continually frequent the infected houses, there assist in attending to the sick, and thus come into contact with the bowel discharges, or else they drink the contaminated water. My inquiries therefore failed to elicit any information on this subject, and owing to the fever having now existed in the town to a greater or less extent for nearly seven years, I was unable to ascertain the manner in which it first originated.

I paid a visit to all the slaughterhouses, and with the exception of one, they were clean. The one referred to belongs to a butcher named Bulliment, and here I found in an open yard, a mass of putrid offal and entrails; I was informed that they are never removed until the butcher "can stand the smell no longer."

From the statements I have made, it is evident that the work which an inspector of nuisances is generally supposed to do, is in Winterton entirely neglected.

Among those groups of cottages to which my instructions especially referred, the only two where I found anything worthy of notice, were those belonging to Mrs. Porkuss and Mr. Bennett. In one cottage on the former property, the privy, into which the bowel discharges of a patient who had died of typhoid fever had been thrown, was situated within 3 feet of the house, the door being exactly opposite the house door and close to a window. Like all other privies, it contained soil to within a few inches of the seat, and emitted a most offensive effluvium. Mr. Bennett's cottages were all clean, and I found no illness there.

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APPENDIX.

No. 3.
On an Outbreak of Typhoid Fever at Guildford, by Dr. Buchanan.

No. 3.—Dr. BUCHANAN'S REPORT on an OUTBREAK of TYPHOID FEVER at GUILDFORD.

§ I. Inquiry into the circumstances of the recent outbreak of typhoid fever at Guildford was made on September 25–27th, and information since received brings the facts down to October 1. An account of the fever must be prefaced by a short statement of some matters relating to the general sanitary condition of the town.

Guildford is placed on the side of a hill of Chalk, where it is cut through by the valley of the Wey. The northern, and more level, part of the town, which extends into the parish of Stoke, are on a bed of Lower London Tertiaries overlying the Chalk. This bed is of somewhat marly sand, and has a maximum thickness of 15–20 feet. But it is with the larger portion of the town, built immediately on Chalk, that this report is most concerned.

The Chalk furnishes a perfect natural drainage for the town. Cesspools sunk into it keep themselves dry, and are commonly so inoffensive that they are not emptied for many years together. The water-line in the Chalk is of course much below the surface of the higher part of the town; at the lower parts water is easily reached at a level a little above that of the river surface; into the river considerable springs from the Chalk constantly pour. The water-level under the town undergoes no appreciable fluctuations, either from changes of season or of artificial influences.

There is no recognized system of closet drainage in Guildford, but cesspools into the Chalk are almost universal. Shallow sewers receive surface water from most of the streets and slops from the houses, and into some of these sewers more or less night soil—chiefly the liquid portions of it—is discharged. This is without the consent of the authorities, as the sewers were never constructed for such a purpose.

The water supply of Guildford is derived partly from the public waterworks, which are fed by two wells sunk some 20 feet into the Chalk at the lowest part of the town; an old well from which water is raised by the power of an adjacent watermill; and a new well from which, from April to July inclusive in the present year, water was distributed to the higher parts of the town by engine power. But of the 1675 houses (1867) of Guildford, only 928 are supplied from these sources, the remaining 747 obtaining their water from private wells and some few from the river.

The population of Guildford in 1861 was 8,032 in 1,514 houses. The population is now estimated at 9,000, and the number of houses is 1,675. There is some subletting of houses, but very little serious crowding in the town. The occupations of the people are various, agricultural and manufacturing, but offer nothing to note in the present report.

§ II. Typhoid fever not unfrequently prevails in Guildford and the neighbouring villages. The district of Guildford stands second highest amongst extra-metropolitan registration districts of Surrey for its deathrate from fevers, but the best local opinion ascribes this circumstance to the frequency of fever in other parts of the district rather than in Guildford itself. In the present summer, cases of

typhoid had occurred from time to time in various neighbouring villages, and some few in the town before the time of the outbreak under question. During the first four weeks of August about 10 cases of fever appear to have occurred in the town, six of them being reported by one practitioner.

In the last three days of August cases of typhoid fever came under treatment in Spital Street and Pannell's Terrace, high lying and usually very healthy parts of the town. In the first two days of September a few others came under observation, and on September 3rd and 4th a surprisingly large number of people sent for medical assistance and were found to be suffering under the same fever. In the first 10 days of the month a total of some 150 cases had come under treatment, and this number had increased to 264 by the end of September.* A singular circumstance soon forced itself on attention in connexion with this outbreak. Whereas the few cases that had previously happened in Guildford had been scattered through the poorer low lying parts of the town, this sudden outbreak was restricted with almost absolute precision to the high levels; well-to-do people were affected as much as the poor; streets in various quarters of the town were affected; the best kept houses were invaded as much as dirty ones. Except the coincidence with high level, there was nothing approaching uniformity in the distribution of the epidemic.†

The outburst reached its greatest intensity before the middle of September, and thenceforth declined pretty rapidly. Meanwhile a very few cases were occurring at other parts of the town. At the time of inquiry only a few new patients were coming under observation, and these were increasing in number in parts of the town that had not been affected by the first explosion.

Looking carefully for any condition which might coincide in distribution with the fever, it was soon seen that drainage could have played no direct part in the result, inasmuch as there is no system of sewers in the town, and the parts affected were those whose natural drainage is the best. Other suggestions having been put aside as not meeting the broad facts of the case, only one condition was to be discovered generally coincident in distribution with the outbreak, and that was the *high service of the town water supply.*

More particular inquiry was then made as to the source from which each affected house procured its drinking water, and it turns out that all the houses *first* attacked at the beginning of September were supplied with water from the high service. A few exceptions to the absoluteness of this rule were in school children and others who, living in houses not supplied by high service water, spent the hours of the day in houses that got their supply from the high service. In the latter part of September new attacks had been less exclusively distributed to such houses.

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* The mortality of the fever cannot yet be stated. Only three cases had been fatal at the end of September. Some other persons who were then ill have died while this report has been in preparation. Evidently the deathrate will turn out to be very low, a fact of interest in connexion with the transitory operation of the apparent cause of the fever.

† The parts affected by the outbreak are all on Chalk. Sporadic fever has shown no preference for the Chalk, rather for the more level and lower lying Tertiary parts of the town.

APPENDIX.

No. 3.
On an Outbreak of Typhoid Fever at Guildford, by Dr. Buchanan.

Of the total number of 264 cases of fever that have occurred in Guildford in August and September, 177 have been in the 330 houses that derive their water from the high service mains; only 30 have occurred in the 598 houses that are on the low service, and 57 cases in the 747 houses that take no water from the public works. Even these figures show an incidence of the fever on the high service houses ten times as great as on the low service; but this does not express the true limitation of the outbreak. If the few sporadic cases occurring before August 28th, and those that did not occur until the end of September, when the disease was getting more diffused, be excluded, there remain not more than two or three dozen cases (out of the 150 that occurred between August 28 and September 10) in houses that did not get high service water. And if deduction be made of the school children above mentioned there remain less than a dozen persons attacked in this fortnight who had not had daily and hourly access to the water of the high service. (*See postcript.*) The experience of all the medical men has been combined in this conclusion; but the practice of the Surrey County Hospital may be quoted in illustration. Careful inquiry by the resident medical officer showed that of 39 cases coming under treatment there between September 3 and October 1 (he had seen no fever for weeks before) 26 lived in houses supplied by high service water, 4 in houses supplied by low service water, and 9 in houses that got water from their own wells. But of these last 13, 10 were children who in August went to schools supplied by the high service water. Two of the other three cases did not come under treatment till October 1, and the third was on September 20th at a village three miles off.*

The coincidence of the fever outbreak with the area of high service water supply being thus strongly marked, and the cause of the disease having evidently come into operation about the middle of August, it was at first sight perplexing to be told that since the beginning of August identically the same water had been delivered to both the high and the low service districts of the town. The engine which pumped water from the new well to the high service mains and to the high service

* Mr. Taylor had had 60 cases of typhoid, little or none before September 3rd. His earlier cases were all in houses supplied by high service water. In all 43 of the cases had been in houses so supplied; 7 had been in houses on the low service, and these included 4 children who went to school in the high service district; 8 were in houses with wells, and of these persons 5 went to school or where employed where high service water was in use; two cases were beyond the town in persons who had worked in houses similarly supplied. Very similar distribution had occurred in the practice of Dr. Stedman, Dr. Morton, Mr. Eager, Mr. Butler, and Mr. Schollick, and the outbreak in the practice of each of these gentlemen had occurred about the same day, and was at first wholly in houses supplied by high service water, scarcely any cases of the fever having been previously under their care. The most numerous cases of scattered fever had been in the practice of Messrs. Sells and Wilson, probably from the circumstance of their holding a poor-law appointment in an unwholesome district. Their experience, though not identical in form with the rest, is wholly confirmatory of the above conclusions. In the first 28 days of August they had no case of fever in houses supplied by the high service, one in a house supplied by the low service, three in houses of the town supplied from wells, and five cases in the the surrounding country. In the 17 days, August 28th to September 14th, the number of attacks among their patients whose houses are on the high service was 22, in houses on the low service three; in houses with wells, nine; and in country parts six. In the 16 days September 15th to September 30th the new attacks in high service houses had diminished to 14, but those in houses supplied by low service had risen to six, those in houses with wells to 10, and those in the country districts to eight.

reservoir had broken down on August 1st, and from that date no water had been pumped from the new well, but the high service mains had been charged by the water-wheel in connexion with the low service, and the water to both services had been that of the old well.

On further investigation, however, it was found that some water from the new well, raised on or before August 1st, had been stored in the new high service reservoir, and that on August 17th, the waterwheel being on that day under repair, this stored water was distributed to the high service houses of the town. It was distributed on no other day and to no other houses. These 330 houses therefore on which the fever almost exclusively fell had received a different water from the other houses of the town, viz., water from the new well, stored up from August 1st, and delivered on August 17th. The statement may be repeated that no other condition could be found, on careful and detailed inquiry, at all coincident with the outbreak of fever.

Analyses of several waters of Guildford, including that which the circumstances mentioned had brought under suspicion, have been made for this report by Prof. Miller. The results with Dr. Miller's comments on them are subjoined.

" Four samples of waters were received duly secured in stoppered glass bottles, and labelled as follows :—

1. Old well, Guildford, September 26, 1867.
2. New well, Guildford, September 26, 1867.
3. Mill Tail, Guildford, September 26, 1867.
4. Guildford new reservoir, October 1.

In the first three samples there was an extremely scanty reddish sediment; the fourth sample was quite bright. No sensible colour, smell, or taste was exhibited in any of the samples, except that from the mill tail, which had a faint yellowish tinge and a slightly musty taste. They are chalk waters and soften considerably on boiling ; and like most chalk springs seems to soften by exposure to the air. That from the reservoir, where it had been standing for two months as Dr. Buchanan informs us, is considerably softer than that taken newly from the well.

There is nothing remarkable in the amount or quality of the saline matter, a little ammonia and a small amount of nitrates are present : the ammonia derived probably from surface drainage ; it is distinctly more in the new well water than in the old. The amount of nitrates is small in all cases. So also is the quantity of organic matter, which however, is decidedly greater in the new than in the old well. After standing in the reservoir for some weeks it appears, as is usual in such cases, to have undergone a partial oxidation, the quantity of nitrates having increased, whilst that of the ammonia and organic matter has distinctly diminished.

The aeration of the water from the old well is perfect ; *that from the new well very defective.* But this water after it has stood in the reservoir (specimen No. 4.) has nearly recovered its proper proportion of oxygen. The water from the new well, No. 2, appears to have contained some putrescible or rapidly alterable substance, which has absorbed a large quantity of the dissolved oxygen which spring water ought to contain.

I subjoin details of the analyses :—

Guildford Waters.	1 Old Well.	2 New Well.	3 Mill Tail.	4 New Reservoir.
Appearance	Nearly bright.			Bright.
Colour	—	—	Slight yellowish	—
Taste and smell	None.	None.	Slight musty.	None.
Clark's Scale. Hardness before boiling	15°·1	16°·2	8°·7	10°·7
Clark's Scale. Hardness after boiling one hour	4°·8	4°·1	3°·9	2°·9
Total solids in grs. per gall.	23·2	24·0	13·4	21·8
Fixed salts	22·7	23·2	12·5	21·4
Volatile and combustible matters	0·5	0·8	0·9	0·4
Nitric acid, N_2O_5	1·20	1·10	0·20	2·05
Ammonia	0·01	0·02	0·01	0·007
Gas in cubic inches per gallon	16·30	19·49	15·22	16·30
Carbonic acid, CO_2	7·74	8·18	4·11	6·19
Oxygen	2·85	1·17	2·89	2·93
Nitrogen	5·71	10·14	8·22	7·18
Ratio of oxygen to nitrogen	1:2·05	1:8·6	1:2·84	1:2·4

Respecting the source from which the water of the new well might have received the impurities detected by Dr. Miller, it was first necessary to consider the accidents to which the well might have been subjected since the time at which its water had been last pumped.* In answer to questions on this point, Dr. Miller has furnished me with the following opinion :—

"I would state in reply to your question, 'Whether the peculiarities 'of water No. 2 from the new well are either wholly or in part accounted 'for, (1.) by the partial stagnation of the water during a period of two 'months ; or (2.) by the entrance of the following substances into the 'well: pieces of wood, oil, cotton-waste used in cleaning machinery ?' That I see nothing contrary to the opinion, that the absorption of oxygen noticed in the analysis should have been occasioned by a partial stagnation of the water in contact with such substances as those above enumerated, particularly the oil and cotton-waste used for lubricating machinery. I should also think it probable that some contamination with animal matter of excrementitious origin had occurred. Though certainly not to any large extent, the presence of ammonia points, however, unmistakeably to this source of contamination."

* The bulk of the water that remained stored in the high service tank on October 1st was, as Professor Miller points out, perfectly clear. But a small quantity containing sediment was procured for me by Mr. Taylor. It showed to the microscope mainly crystals of carbonate of lime with much organic detritus, among which fragments of decomposed dotted, woody fibre were distinguished ; and broken portions of some entomostracean. Nothing was seen resembling a fungus neither in the first deposit nor in the lighter secondary sediment from the water.

The next point for consideration is how excrementitious matters could have got into the new well. Not analysis only, but physical considerations show that the new well is supplied by a different spring in the Chalk from that which feeds the old well: for the old well is unaffected in level when the water of the river is drawn off; the new well is reduced in level on such occasions. Then it is known that the new well gets its water not by percolation only, but from a fissure in the Chalk: for at the time of construction of the new well very little water was obtained, till, somewhat suddenly, an abundant supply was reached, so abundant that the ordinary power of the engine could not empty the well. Now into this fissure or into the Chalk around the well, it was certainly easy for excrementitious impurities to have entered. A sewer runs within 10 feet of the well, through which sewer the iron delivery-pipe of the high service passes. The same intense vibration (alleged to have been due to the want of a valve in some critical situation), which broke down the engine on August 1st, is found to have loosened the bricks in this sewer, and to have caused some escape of its contents, though not to any large extent. The sewer, though in the main receiving surface water only, receives the excreta from certain waterclosets and the overflow of certain cesspools in and about South Street; and into a branch of this sewer in an adjacent alley, just above the fracture, certain privies used by many poor families also discharge the liquid portion of their contents. There is reason to suspect other leakage from these drains and sewers, all of which are on a higher level than the well, and are in close neighbourhood to it.* [*See Postscript.*]

Mr. Taylor and the surveyor have kindly helped me to inquire whether impurities derived from this source of probable contamination could have included in them any specific typhoid matter. It appears that at one house in South Street there was a case of typhoid fever in July under the care of Mr. Sells, but the slops only of this house pass into the sewer and not the matters from the watercloset. In the houses that drain into the sewer and lie near the new well there was typhoid fever a year ago, but none since.†

It here arises to point out that not only this particular new well, but many of the wells of Guildford, must be exposed to danger from sewage

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* There is no chance of impurities having entered the water while it was stored in the new reservoir. This is covered, high on a hill and away from all detectable risk.

† Another suggestion has been made as to sources of impurity in the drinking water of the town. There exists a communication between the river and the pipes of the waterworks. This is said to be very rarely used, and only for the purpose of getting a first sucking power to the pumps; and it is stated not to have been used at all during the present summer. However, since the termination of this inquiry, a specimen of water has been sent to me that was taken direct from the high service mains at Charlotteville; it contains much dark sediment, and shows by the microscope diatomaceæ and other organic forms that have almost certainly been introduced from the river. It will be remembered that the water now being supplied to the high service mains is professedly wholly from the old well. Could some river water, temporarily and even without knowledge, have been on some previous occasion delivered to the high service system? At all events it is to be wished that any communication whatever with the river should for the future be discontinued.

P.S., Dec. 31, 1867. A paragraph in the "Lancet" of November 30th, states that "it is now known that there were not only means of conveying the water of the river Wey into the well supplying the town with water, but that it was the practice three times a week to turn the river water into the well." But according to the most accurate information obtained both at the time of the original inquiry and lately in answer to direct questions it does not appear that there is any foundation for this statement.

contamination, and latterly to a much greater extent than formerly. Until the last few years the ordinary house cesspool into the Chalk received but little liquid matter, but recently the Local Board, with the object of keeping down cesspool emanations, has had the privies converted into trapped waterclosets (still connected with the cesspools) requiring a great deal of water to be thrown down them to keep them clean. No doubt the great advantage of keeping away stinks is procured by this means, but it must be at the cost of saturating the porous soil much more rapidly with the soluble parts of cesspool contents. A risk is thus introduced of passing into the wells incompletely oxidized derivates of excrement; especially if the well be near to a cesspool, or if it be supplied by considerable fissures in the Chalk, would this risk of polluting the wells become formidable.

A point in the natural history of typhoid appears to receive elucidation, if the deductions of this report as to causation are correct. The water which is believed to have been the "cause" of the outbreak was delivered on August 17th, and on that day only. The first cases of the fever came under medical observation on August 28th; after that two or three each day, and a very large number on September 3rd and 4th. With allowance for the varying time that would elapse in various cases between the occurrence of the first symptoms of typhoid and the sending for a doctor there is enough correspondence in these dates to fix the occurrence of the first symptoms in a great proportion of cases on or about August 28th, or 11 days after the operation of the cause. Inasmuch as other cases occurred in considerable numbers for several days after September 4th, it may be that in those cases there was a longer incubation period. This does not, however, upon such information as is available, appear to have been necessarily the case; for many of the high service houses are furnished with cisterns and others with large underground tanks in which the water received on August 17th would be stored; mixed, indeed, more or less with other water delivered before and after, but not necessarily losing any noxious quality it might have possessed until a considerable number of days had elapsed. The houses in Pannell's Terrace were attacked particularly early and suddenly. These have no cisterns, but take their water direct from the mains.

POSTSCRIPT, December 31.—Mr. Taylor writes, December 21: "I take upon myself to inform you that your suspicions as to the percolation of sewage matters into the new well have been now rendered almost certain. The engineers employed in the repairs of the steam engine noticed some exudation on the wall of the engine house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine house. The sewer was found leaking in various places and the soil between it and the wall of the engine house was saturated with sewage of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain constructed with red unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark coloured fetid slush

MAP OF TERLING
Church
Terling Place
Scale 20 In. to the Mile.

had to be dug out and and removed in baskets, making the men vomit who were employed in the work."—Mr. Taylor further informs me that the whole number of deaths from fever, up to the end of the epidemic was 21, including three or four who died in other districts after removal from Guildford, and that the last death was on Nov. 22nd. On a rough computation, he gives the total number of cases of fever from August to December at 500. He mentions that among the few early cases ("less than a dozen," *text*, p. 36) of fever which did not appear to be connected with the area of high service water supply, he has since learnt that three children are included who shortly before their attack went from their home in another part of the town to a house within the high-service area, and there drank freely of the water supplied to that house; it was a house where three deaths from fever subsequently occurred.

No. 4.—REPORTS on an EPIDEMIC of TYPHOID FEVER at TERLING, by Dr. R. THORNE THORNE.

No. 4.
On an Epidemic of Typhoid Fever at Terling, by Dr. Thorne.

FIRST REPORT.

(Jan. 25th, 1868.)—THE Lords of Her Majesty's Council having been informed that a serious and sudden outbreak of fever had occurred in the village of Terling, in Essex, I was instructed by their Medical Officer on the 21st of December 1867, to proceed to the spot in order to examine into the causes and nature of the disease. I accordingly went to Terling on that day, and remained there till the 25th of December, and on the 6th of January I, with renewed instructions, again visited the place, and again remained there until the 13th. I now beg to report the result of my inquiries on those two occasions, and of the communications which I made to the local authorities.

Description of place.

Terling is situated in the Witham Union, and lies four miles to the west of that town. According to the investigations made by Mr. W. Whitaker of the Geological Survey of England, it is placed on a bed of London clay, which comes to the surface at the bottom of a small valley down which a stream flows; on either side it is covered by a plateau of gravel and occasional beds of sand, on which, with one or two exceptions, all the dwellings stand; further still from the stream, and outside the village, lie patches of Boulder clay, known locally as Marly clay. The country for many miles around is generally flat; land springs are most plentiful; water is found in great abundance in ponds and in ditches by the roadside, and the atmosphere is unusually moist. Here, as almost throughout the county, the smallness and scarcity of the streams show that a great portion of the rain that falls penetrates downwards. The village itself, though scattered over an area of several miles, is principally collected on the gradually sloping banks of a rivulet named the Ter, which, flowing southwards, empties itself into the Blackwater river; these banks, however, are of a very undulating character. Setting aside Terling Place, the residence of Lord Rayleigh, and the Vicarage, hardly anything but labourers' cottages are to be seen throughout the village, and these are almost without exception of the poorest description; many are constructed merely of lath and plaster, connected by beams, with a thatched roof, and the whole fixed on a basis of brickwork; others consist in great part of wood, which is often in a rotten or worm-eaten state; some again, of more recent date, are built of brick.

The inhabitants of Terling present many characteristics of great interest. They are all very poor, the general wages for the men, varying year by year from 10*s.* to 12*s.* a week, some receiving 13*s.* and 14*s.*; many seldom taste fresh meat, and a few of them only occasionally procure a piece of bacon or a herring. I saw one Sunday dinner table spread only with carrots, turnips, and a plain dough pudding, even bread was absent. The ordinary dinner consists of bread and cheese.

Characteristics of population.

Socially there is nothing which can tend to raise or elevate the people; no middle-class exists for them to imitate, or to which they can aspire to rise; there is almost a complete gap between the few wealthy residents and the poor labourer. The population is about 900, and for a long time there has been no variation in this number; this I was told has been mainly due to the fact that new-comers have not, as a rule, been well received there, owing to the desire not to increase the parish rates, and the passing of the Union Chargeability Act has not as yet occasioned any difference in this respect. From the description which I received of the villagers it appears also that they have a tendency to isolate themselves, many hardly ever leaving their own parish, even to visit a neighbouring village, and hence they intermarry to such an extent, that "half the people are related to each other." They are intellectually and physically of a low type, there are among them eight or nine idiots and imbecile children, all seem dull of comprehension, and "hardly a well-built man is to be seen." An extraordinarily large number of them are the victims of phthisis and scrofula; this may be partly accounted for by the numerous intermarriages, partly by the moisture of the soil and the atmosphere, and the entire absence of all drainage. Ague was very prevalent throughout the neighbourhood until about the year 1840, but it is now only seen on rare occasions. There is much intemperance in the place, illegitimate children abound, sometimes many in one family, and so distinguishing a merit is it deemed for a girl to marry without being pregnant, that to each such bride, a principal benefactress of the village is in the habit of giving a special wedding gift.

Administration of sanitary law in the place.

At Terling all the nuisances which are generally associated with outbreaks of typhoid fever exist in great and unusual abundance, and all that is necessary to produce contamination of air, soil, and water is to be found throughout the village. The cottages are literally surrounded by every species of nuisance that it is possible to conceive; slops and ashes are thrown down on the unpaved yards and gardens; manure heaps, cesspools, and masses of decaying vegetable matter lie round about. The privies, none of which have a properly constructed tank for the reception of fæcal matter, are in many instances in a most dilapidated state, and owing to their being frequently constructed of wood, the back is in part broken away, and the filth either lies in masses on the ground, or else is collected in large holes which have been dug out for that purpose; and as Lord Rayleigh has granted allotments of ground to his tenants, they cherish and store up these foul accumulations, nominally for the purposes of manure until they assume a magnitude which none but those who have seen them can believe in. Surrounding one cottage and within a circumference of 20 feet of it, I found one pigstye, three manure heaps, two cesspools, and a privy, the contents of which extended about 12 feet down an adjoining field.

In the central part of the village, each cottage, or each group of two or three, has its own well, and if the ground is at all undulating, it is invariably placed at the lowest point. These wells which are all sunk in the gravel, are as a rule uncovered, and are merely lined with bricks placed loosely one above another, without any cement or plaster; their depth, which varies from about 5 feet to 40 feet, agrees with

increase in the rise of ground. On a higher level than these wells and everywhere surrounding them, lie the various nuisances just enumerated, and since the soil is of a very loose and porous nature, and one which easily admits of the percolation of fluids, the closeness of such sources of contamination to the cottagers' drinking water is seen to be fraught with the greatest danger. Some of the cottages lying in the outskirts of the village have no wells, and those who reside in them are therefore compelled to fetch their drinking water from ponds in the addjoining fields. All the drainage from the field ditches, and at times from the roadsides runs into them, the cattle frequent them, and in summer they are, to use the expression of a resident, "nothing better than stinking pools." In only one instance did I find that the river water was used for drinking purposes, but in this case at a point where the stream was little better than a sewer.

Prevalence of overcrowding.

Overcrowding is almost everywhere met with, and at the present time it exists in its worst form; two and three fever patients are frequently seen lying in one bed, whilst several of their healthy relatives occupy the same room. In one instance I found a woman suffering from the epidemic disease, occupying with six of her family, a bedroom measuring only 10 feet long by 9½ feet broad, and 6 feet high, the chimney was blocked up, and the only window was less than 3 feet square. Here each individual had less than 82 cubic feet of air, and ventilation was, as indeed almost everywhere, entirely neglected.

Description of epidemic.

The epidemic from which Terling is suffering is well marked typhoid fever. Cases of this disease, Dr. Gimson states have been seen about the village for five years (his knowledge does not extend further back), and in Dec. 1862 and the early part of 1863 about 40 cases and five deaths occurred; since then occasional instances have been met with, and during the past year at least one case has been seen every second or third month. The present outbreak is most alarming both in its magnitude and the suddenness of its occurrence. Almost entire families are attacked, a father only remaining in some instances to nurse and attend to his wife and a large family of sick children. The disease is of unusual severity, the characteristic rose spots are very abundant, and hœmorrhage from the bowels exists in a large number of cases; great prostration of the nervous power is evident from the first day of the affection, and in some instances the patient seems to be almost instantly overwhelmed with the intensity of the poison. A woman who is at her washtub one day is dead three days after, a girl strong and hearty at the commencement of the week, passes rapidly into a state of insensibility and dies in a few days, before the special characteristics of the disease have had time to manifest themselves. On the 13th of January 1868, 208 persons had already been attacked by the prevailing malady, and several fresh cases were daily occurring. I do not include in my number cases of so-called diarrhœa (possibly all mild cases of typhoid fever) which were only accidentally heard of and which probably were numerous, though not of sufficient severity, to call for medical relief.

With one exception hereafter to be mentioned, the disease seems to date from Dec. 4th; during the following 10 days 30 fresh cases were seen, but on the 15th, 16th and 17th by far the largest number were attacked, 22, 19 and 12 cases occurring respectively on those days. After this though the daily number of fresh cases was by no means so large, still a steady increase took place. The villagers were everywhere alarmed, for owing to the many intermarriages, everyone had several

relatives attacked, some dangerously so. As yet, however, only one death had taken place, namely on Dec. 14th; but, when the third week of the epidemic had arrived a steady and gradually increasing death rate commenced, and on the 30th, twelve of the patients had died, and others were dying. Terling was now completely panic-stricken, and the moral effect of the tolling of the church bell at the death and funeral of the parishioners seemed so prejudicial not only to the sick but also to those who still remained unaffected, that I thought it right to suggest to the vicar the immediate discontinuance of that ordinary custom. Women with tears flowing down their cheeks called from their cottage doors for help, and everyone seemed to dread the prevailing disease. No class of persons was exempt; the rich, the well fed and clad, were attacked in common with the poor and destitute. At Lord Rayleigh's residence 10 cases had occurred, the Vicar's house was a seat of the epidemic, and from one end of the village to the other, the disease seemed to be almost evenly spread.

Effect of age and sex on epidemic.

Age and sex seemed to present remarkable peculiarities, thus: out of 145 cases whose ages I was enabled to obtain, 79 were children under 14 years of age, and of the remaining 66, 50 were females, leaving only 16 males whose ages exceeded 14 years, out of the entire number attacked. This I believe is to be accounted for by the fact that the men and the majority of the boys over 14 years of age, spend the greater portion of their time away from home, labouring in the fields, and that they principally drink beer, whereas the women and children are left at home, and procure a considerable portion of their beverage from the wells; the children drinking directly from them much more frequently than the women, owing to the latter consuming a good deal of tea, in making which the water is of course boiled.

Description of first case of typhoid fever.

The first case of typhoid fever which has occurred in Terling for two or three months, is that of a young woman who lives at Lord Rayleigh's dairy (vide map, A), and the attack, in this instance commenced on the 13th of November. A month previous to her attack however, it appears that she had just returned from Somersetshire, and a few days after her arrival at home, she was seized with diarrhœa, or as she terms it, "a bilous attack," which she thought was induced by drinking beer, after having for some time been accustomed to cider. This indisposition lasted for about three days, and then passed off; but three weeks afterwards, however, an unmistakeable attack of typhoid fever, marked with an abundant eruption of rose spots, and severe hœmorrhage from the bowels commenced. When I first saw her on December 22d, her bowel-symptoms had but recently ceased, and she was still in a very prostrate condition. This patient, in common with her father and mother, procures all her drinking water from the river which flows by the side of their house. The water, which has a very dirty appearance, is collected at the foot of a few steps leading from a yard down to the stream. Three feet from this spot, a pipe which conveys all the drainage from the yard and the wash-house, empties itself into the river, and 12 yards lower down the stream is the privy which belongs to the dairy, the entire contents of which fall into the water. On making inquiries, I found from those who lived here, that at times, owing to the scarcity of water, the river at this spot is in nearly a stagnant condition, and the water must therefore under these circumstances become well saturated with fæcal matter, to say nothing of the surface drainage. But in addition to this, the dairy lies at the extreme south of the village, and since the stream flows towards it, the contents of several ditches which I saw passing from privies to the water's edge, must

be washed past the very spot where these persons collect their drinking water. It becomes a question whether this young woman could have imported the fever from Somersetshire, and whether the diarrhœa which occurred immediately after her arrival at Terling, was not a part of the disease which, after apparently subsiding, manifested itself again three weeks afterwards; she, however, had certainly not to her knowledge been amongst persons who were suffering from any disease at all. It is also possible that her fever may have been brought on through drinking contaminated water, although the mother of the patient assured me that it was always boiled before anyone used it.

I made careful inquiries, in order to ascertain whether it was possible that the milk supplied from this dairy, could, after having been diluted with the river water, have caused the general outbreak. Nothing, however, seemed to support this idea, for the milk is the property of Lord Rayleigh, and the dairy-woman receives from him a weekly stipend quite irrespective of the quantity of milk which she sells. The majority of the villagers drink skimmed milk which they obtain at a nominal price, and it is evident that by adding water to it, the dairy-woman would only be giving herself additional trouble, without being in any way a gainer, and her denial of such a practice is all the more to be depended on, because the inhabitants of those cottages where there has been no disease during the epidemic, get their milk from this dairy as well as those amongst whom typhoid fever has been so prevalent.

Connexion of epidemic with variations in height of surface water.

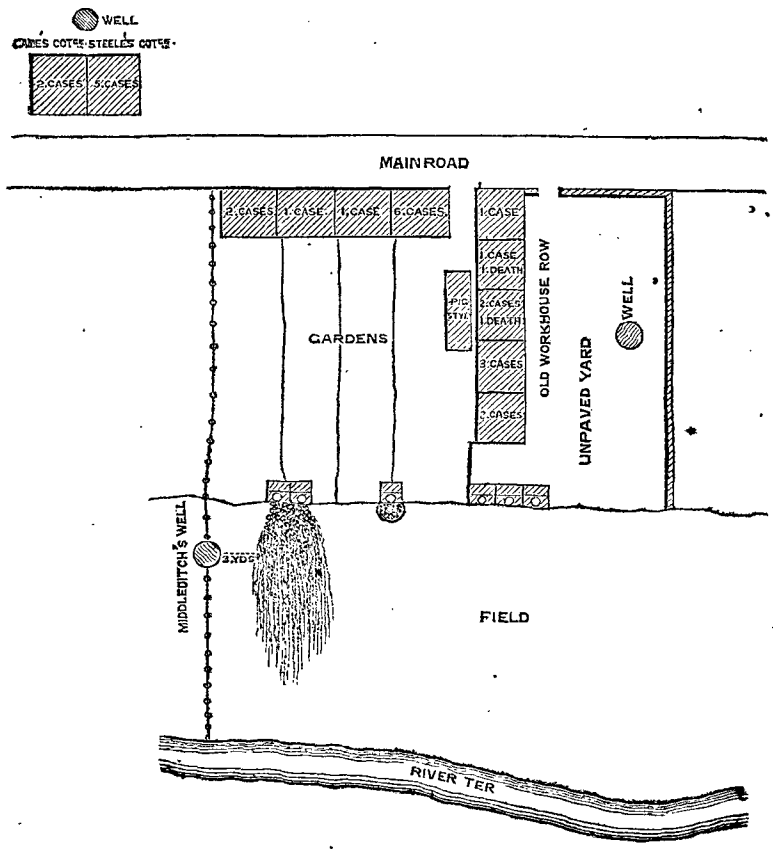
Before describing a few of the most interesting examples which occurred during the general outbreak, I would note that some of them seem particularly to illustrate a question at present under scientific discussion. The general tendency of the evidence which I obtained, is to the effect that the water supply of Terling was the great infective influence, and it will be observed that some of the following cases not only conduce to that general conclusion, but also seem very definitely to connect the outbreak of disease with a particular change in the level of the surface water. Everywhere I was informed that the water in the wells had gradually sunk during the latter part of the summer and autumn; in the shallow ones this had been unmistakeably seen, in some of the deep ones I found that the rope holding the bucket had to be let out to an unusual length, and in one instance I was told that after the latter had been lowered into the well, such was the scarcity of water, that it had to be oscillated to and fro, in order to get any in. The date at which the water reached its lowest point varied according to the altitude on which the well was placed, and also to its depth. One had been empty two months preceding my visit, a second three weeks, in others the water had been gradually sinking until the latter end of November. Following this drought, came a sudden flow of water into all the wells, and this I was generally informed took place about three or four weeks before I arrived at the village. In three cases, however, I was enabled to ascertain the exact period of its occurrence, and thus to trace out the connexion which it bore to the disease. A few instances will make my meaning plain.

Illustrations of the circumstances of the attack.

In one of the most populous parts of the village stands a row of five cottages, ill-constructed and badly ventilated; they are built of wood, and are called the Old Workhouse Row (vide map, B.) Behind them stand some pigstyes and accumulations of refuse; ashes and slops of every description are evidently thrown into the yard in front, which is unpaved and the ground has every appearance of being sodden with filth. In this yard is an uncovered well for the use of those who inhabit the row. At cottage No. I. there has been one case of typhoid fever, at

Illustrations of the circumstances of the attack.

No. II. one case and one death, at No. III. two cases and one death, at No. IV. three cases, and at No. V. two cases. The water in the well I ascertained had very gradually sunk during the summer, and after having remained empty for about two months, during which time all those living here procured their water from a neighbouring well, bearing the name of "Middleditch's well," (vide map, C), it rose again towards the end of November. A woman living in the first cottage was delivered of a child on the 19th of November, and she experienced considerable inconvenience owing to there being no water at hand with which her linen could be washed. Exactly one week after the birth of her infant, that is to say on the 26th of November, water was again found in the well, it was immediately procured for the use of her house, and it was also on that day used for drinking purposes. The first case of fever in this row occurred in this woman's family on the 6th of December, 10 days after the rising of the surface water, or in other words, the period which elapsed between that event and the outbreak of the disease corresponds to what is generally admitted to be about the period of incubation for typhoid fever. On the 9th of December, two more cases occurred in this same block of cottages, another on December the 12th, and three more on the 15th At first sight the connexion between these latter cases and the rise of the water seemed to be less distinct, but on inquiring more minutely into the matter, I ascertained that in all the other cottages, although



the water was used for scouring the floors from the first, yet, owing to its not having its normal bright and clear appearance, all the drinking water was brought up from Middleditch's well for several days longer, but the exact number of days I was in no instance able to ascertain.

Illustrations of the circumstances of the attack.

Another instance in every respect similar to this one is that of two cottages occupied by families named Steele and Game, close to the Old Workhouse Row (vide map, F); their common well having been empty for three weeks, they also sought their water from Middleditch's. Seven cases of typhoid fever have occurred here, and though perfectly accurate dates could not be ascertained, the disease had evidently broken out about a fortnight after they were first able to procure water on their own premises. Standing again close to the Old Workhouse Row, and at right angles to it are four cottages, in the first of which six have been affected, in the second there has been one case, in the third two cases, and in the fourth two cases. These cottages have gardens behind them, at the end of which are situated three privies, one stands alone, and its entire contents are collected in a huge hole behind it in an adjoining field, the other two stand together and empty their contents on to the same field. Into one of these a very large amount of soapsuds and water is daily thrown from a wash-house, these become mixed with the fæcal matter, and the whole runs in a large mass, which subsequently divides into several streams for about 20 yards down the field which slopes towards the river. This portion of the field is so saturated with fæcal matter as to be converted into a foul swamp, which I found it impossible to walk across. Three yards from the margin of this flow of filth, and at a very much lower level is the well referred to as "Middleditch's. It is about 5 feet deep, and owing to its very low situation it is never known to be empty. This well supplies the four cottages just mentioned, and it is impossible that it can be otherwise than seriously contaminated by the fæcal matter running from the above-named privies, indeed from its position it is evident that the water supplying it must pass through the very ground into which the filth sinks, and hence it becomes in plain terms a filtrate of human excrement.

The question now arises, was the contaminated state of this water during the period of scarcity the cause of the fever in the Old Workhouse Row, and in the cottages occupied by Steele and Game? This may fairly be answered in the negative, first, because none of the cases occurred during or immediately after the period in which it was used by those living in these places, and secondly, because the first symptoms of the disease corresponded with the time at which they all discontinued using it, owing to their being able to procure water from their own wells. But the outbreak in the four cottages at right angles to the Old Workhouse Row has still to be accounted for. Now, although I was unable to get distinct proof that any change had occurred in the height of the water in Middleditch's well, we may conclude that it did not form an exception to the general rule everywhere else observed, and the propriety of this conclusion is confirmed by the fact that in the case of a well called "Lines' Well," (vide map, D), which is situated on even a slightly lower level than Middleditch's, and like it is never known to be empty, the fall and the rise of the water were observed to take place, although not to so considerable an extent as in wells which were placed on higher ground.

In another part of the village are two cottages, the first of which is occupied by a family named Aves, and where I saw five well-marked cases of typhoid fever, in the second I saw one (vide map, E). About 10 feet from these cottages and in a garden belonging to them is

Illustrations of the circumstances of the attack.

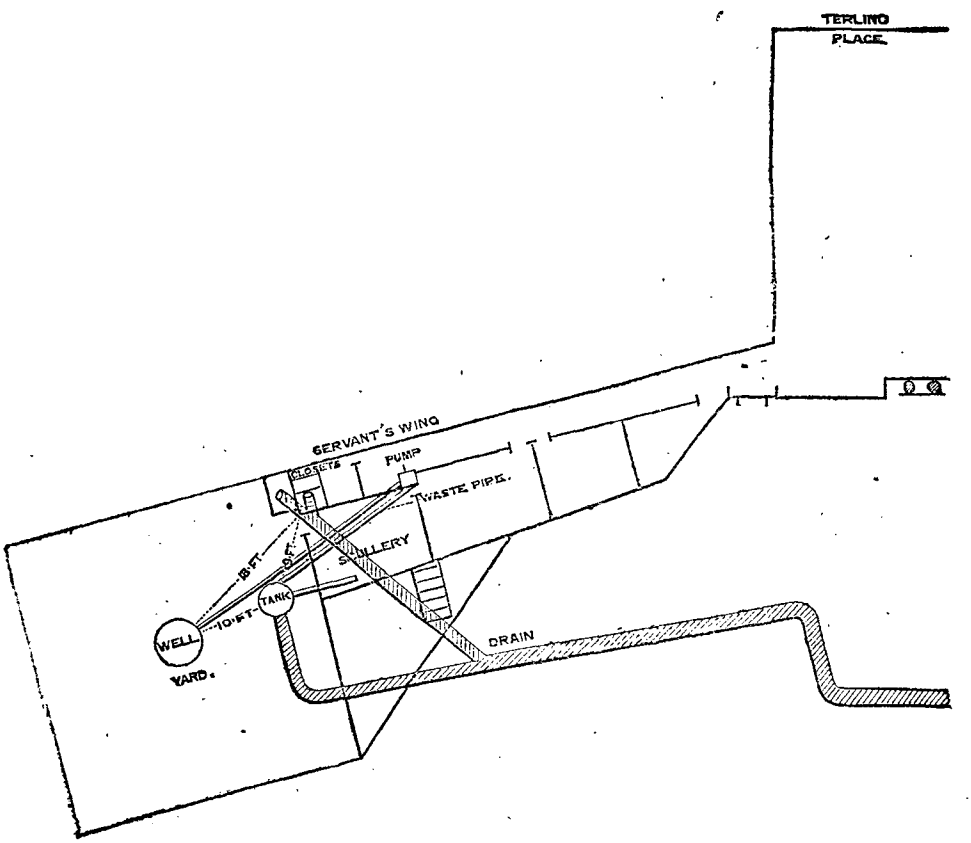
situated the well; 20 feet from this well is a deep cesspool loosely lined with bricks which contains the drainage from the privies of an adjoining large house, and within 12 feet of it a privy which pours its contents into a second cesspool. The water in the well I was informed had been exceedingly low, especially about the 20th of November. The woman from whom I derived this information, and who lives in the first-named cottage was taken ill a few days after this date, and was unable to leave the house for an entire week. Almost the first time she ventured out she went to the well, and she remembers being surprised that the amount of water in it had so greatly increased during her short illness. This visit to the well, took place about the 29th of November, but my informant not being able to speak with perfect accuracy, it may have occurred one day prior to, or subsequent to that date. The first case of typhoid fever in her cottage was that of her daughter Susan Aves, who was attacked on the 16th of December, and whom I saw apparently in a dying condition; four others occurred soon after.

One more instance also tends to the same conclusion. A family named Edwards live in a cottage near the river, and two of their number were suffering from typhoid fever at the time of my visit. Their well is placed in a garden by the side of their house. From this well, which is at about the lowest point, the ground gradually rises in almost every direction, and within 26 feet of it there are two manure heaps with a cesspool between them, and three privies, two of which belong to some neighbouring cottages. Behind each of these privies is a hole in the ground for the reception of their contents; this receptacle in the case of the central one is of an enormous magnitude, measuring about 12 feet broad by 15 feet long, and so crammed is it with fæcal matter that its contents have been poured a few feet down an incline, and have there burrowed out a second cesspool nearly 12 feet long by 8 in breadth. In addition to the above-named nuisances a pigstye is also placed near the well though on a slightly lower level. This well which has been referred to as "Lines' Well," and which is about 5 feet deep, is lined with bricks simply placed one above another, and the edges of these bricks have a blackened appearance. It lies very low, and consequently is never empty, but it is evident that the height of the water in it has participated in the change everywhere else observed, for when speaking of its appearance being turbid, I was informed that this was due to the well having recently been suddenly filled. No one could give me the exact date of this occurrence, but I ascertained that it took place at about the same time that it was observed in the other wells in the village.

One more example is worthy of detail, owing to the fact that the spot which was attacked was an almost isolated one, the patients also were all living, surrounded by comfort and plenty, and apparently placed under the most perfect hygienic conditions. Ten cases of typhoid fever have occurred at Terling Place, which is situated on an estate lying at the extreme south of the village. Here, as elsewhere, the severity of the disease has been very great, four of the patients having suffered seriously from hœmorrhage from the bowels, and three have died. All of those affected were servants residing in the establishment, and although they occasionally frequented the village, in no instance could I ascertain that they had drunk any water from the wells. The portion of Lord Rayleigh's residence occupied by the servants is a wing almost entirely detached from the house, only communicating with it by a small door. In endeavouring to ascertain the cause of the

Illustrations of the circumstances of the attack.

disease here, I naturally turned my attention to this part of the building. At the end of a long passage stands a pump, the water from which is only used by one member of the household with the exception of the servants. This pump is supplied from a well 40 feet deep which is situated in a courtyard at the end of the servants' wing, and the pipe which passes from the well to the pump crosses a brick drain leading from two water-closets. This pipe which is a leaden one I found to be perfectly sound throughout. The drain was then opened, and on examining it, it was evident that the mortar which was used to cement the bricks together was almost destroyed, and at the side of the drain which is nearest the well, a leakage had evidently taken place into the surrounding ground, which had a fæcal odour. Nine feet from this drain and about midway between it and the well is a bricked cesspool,



or tank, which ought only to receive the dirty water from the scullery, the waste water from the pump, and the rain from a portion of the roof On opening it, however, I was struck, as was also a servant who accompanied me, with the fact that the odour was most distinctly of a fæcal character. The distance from the drain to the well is 18 feet, and the soil here as elsewhere is loose gravel, and easily allows

Illustrations of the circumstances of the attack.

of the passage of contaminating matters. This well might have become fouled either directly by the leakage from the drain, or indirectly by the passage of the foul fluids first into the cesspool, which is not watertight, and then from it on to the well. One point worthy of remark is that the outbreak at Terling Place occurred simultaneously with that throughout the village, and we may fairly assume that the water in the well here had risen at the same time with that in the other wells, although, owing to its being a covered one, this fact had escaped observation. I would, however, state that a very bad odour had been noticed to rise up the waste-pipe leading from the pump to the tank in the yard; this for some weeks had been complained of in the servant's wing, and by some residing here, was considered to be the cause of the fever. The leakage from the drain into the tank could easily have given rise to this odour.

On the outskirts of the village, as already mentioned, the cottagers in many instances procure their water from the neighbouring ponds, and here it was in many cases not easy to ascertain the exact source of the disease, my difficulty in this respect being much increased by the low intelligence of the people. In some families, however, children only were attacked, in others the children had been attacked first. These all daily attend the village school, and those who live some distance from it do not return home in the middle of the day for dinner, but they take a piece of bread and cheese with them in their pockets, and procure water where they best can; some drink from the school pump, others naturally run about the village with their companions and therefore would be almost sure to frequent some of the wells which are undoubtedly contaminated. I found that the source from which this school derives its water was a well placed in such a position as to forbid the idea of any possible contamination. A leaden pipe, however, leading from it to the pump passes only 6 feet from a cesspool, but had not so far as I could ascertain any defect in it; this pipe will, by my advice be conducted to the pump by a safer route.

During my visit I carefully examined every well throughout the village, and I found that with very few exceptions they were all so placed that the water they contained could easily become contaminated. Two of those which were placed under the exceptional circumstances, and which on the map are respectively indicated by the letters G and H, deserve notice, because they supply with water the only two large groups of cottages in which none of the inmates have suffered from the disease.

It is evident that for years the land springs supplying the village must have washed the foul materials which had soaked through the ground into the wells, although, owing to the water being very abundant, the contaminated solution thus formed was very much diluted. In connexion with this I would call attention to the statement which I have made to the effect that typhoid fever had existed in Terling for at least five years. Recently, however, although the soakage of filth into the ground has been going on, there has been a deficiency in the water supply; that filth must therefore have accumulated until the rise in the surface water took place, when the whole would naturally be washed from the surrounding ground into the wells, and thus give rise to an intensely saturated solution. Great interest, therefore attaches to the ætiological relation which exists between this very severe epidemic of typhoid fever and the state of the water supply: and it deserves the more notice because the facts observed are not in accordance with those

noticed in Munich by Professor Buhl of that city ;* for the outbreak of the disease did not coincide with the period when the wells were low, but, on the contrary, evidently dated from the time when the water was regaining a high level.

In the cases of three wells, namely, those belonging first to the Old Workhouse Row ; secondly, to the cottages occupied by Steele and Game ; and, thirdly, to that occupied by Aves, I was enabled to ascertain the exact period of this occurrence, and in these we have distinct and unmistakeable evidence that the epidemic commenced in the one instance 10 days, and in the others about a fortnight after the rise of the water in the wells, and although I failed elsewhere to obtain dates which so accurately showed the connexion which this bore to the disease, yet there was everywhere abundant proof to this important fact, that immediately after an exceedingly rapid rise in the surface water,† which had been preceded by an *unusually* prolonged period of drought, an epidemic of typhoid fever of very great magnitude and intensity broke out in this village.

Local authority for removal of nuisances in Terling, and its proceedings.

The nuisance authority for the village of Terling is the Board of Guardians of the Witham Union, and from what I have stated, it must be seen that this authority had entirely neglected its duty. On the 23rd of December I was present at a meeting of the Board ; I explained to them the serious nature of the epidemic which had broken out in Terling, and pursuant to my instructions urged upon them the necessity of prompt and energetic action as the only means by which the fever could possibly be arrested. I especially directed their attention to the importance of seeing, first, that the filth which was so abundant should be removed after it had been disinfected ; secondly, that the inhabitants should at once be provided with a pure water supply, and thirdly, that means should without delay be adopted to remedy the overcrowding. The Board apparently saw the importance of following the advice given, and immediately gave orders for a large quantity of disinfectants, which were at once distributed to the cottagers and applied to the various nuisances. Permission was also given to all the medical men (not exclusively the parish doctor) to order wine, brandy, and beef tea to any amount which they thought necessary for their patients, and the more effectually to carry out these measures a kitchen was procured where the beef tea was always kept ready made. Unfortunately these precautions had hitherto been neglected although the expediency of adopting them had been brought under the notice of the Board. On the 13th of January 1868, I again attended a meeting of the Board of Guardians, and it is much to be regretted that I was obliged to call their attention to the fact, that though they had been profuse in their supply of disinfectants, they had very seriously neglected the removal of the nuisances around the cottages, and I informed them that the steps which they had taken to effect this object were quite inadequate, for though the disease had then been lasting for six weeks, cesspools could be found full to the brim, and those which had been emptied were filling again.

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* Professor Buhl, in an article contained in Vol. I. of the *Zeitschrift für Biologie*, states, as regards Munich, that with the fall of the water typhoid fever makes its appearance, and that the magnitude of the outbreak depends upon the rapidity of the fall, but that when the water again rises the fever disappears, and this quickly if the water rises quickly, slowly if the reverse occurs.

† The rise in the surface water was due, either to a fall of rain, or to the melting of snow ; but, no meteorological observations having been taken on the spot, I am unable to speak with perfect accuracy on this point.

I explained to them, that, had they originally performed their duty as a nuisance authority, the epidemic in Terling would never have occurred, and the lives of the villagers would have been spared, and that therefore, the least which could now be expected of them was an energetic performance of their every day duty. The necessary works to supply pure drinking water had been ordered by the vestry of Terling in consequence of a letter which, in accordance with my instructions I had addressed to them; and by way of preventing a recurrence of this disease by the well-water becoming saturated with the contents of privies, Lord Rayleigh informed me that he was supplying all his cottages, that is to say, 78 out of the 164 in the village, with properly constructed bricked cesspools lined with cement, and effectually covered over.

ACCOUNT by PROFESSOR MILLER, F.R.S., of KING'S COLLEGE, LONDON, of four specimens of TERLING WATER, namely :—

1. Water from Middleditch's well, Terling.
2. Water from village school, Terling.
3. Water from Lines well, Terling.
4. Water from the pump at Terling Place.

Of these waters, No. 2 may be said to be unobjectionable. It is a chalk water which softens considerably on boiling; contains no sensible quantity of ammonia or nitric acid, and is nearly free from chlorides; the amount of organic matter is but small, and it exerts very little reducing action upon the permanganate of potash.

In point of quality, No. 4 comes next. It is not a first-class water. It contains a considerable amount of organic matter, though not in an active state, as it exerts but little reducing effect upon the permanganate. The quantity of ammonia is insignificant, but that of nitrates is more important. The quantity of sulphates and chlorides is small, but though less hard before boiling than No. 2, it does not soften so completely on boiling. The aeration is less perfect than that of No. 2.

No. 1 is a bad water. It contains a large proportion of nitrates, and of ammonia, the quantity of chlorides is considerable, and these three circumstances point to contamination with animal refuse. The amount of organic matter is not large, but it appears to be in an active state of decomposition, as it rapidly reduces the solution of the permanganate. The aeration is imperfect.

No. 3 is a water analogous to No. 1, perhaps not quite so objectionable, as it contains less nitrates and ammonia. On the other hand the proportion of organic matter is large, and it exerts a considerable reducing action on the permanganate. The amount of chlorides is considerable, and nearly all the lime is in the form of sulphates. It scarcely softens at all on boiling; aeration defective.

I may remark that the use of permanganate of potash in such cases is valuable as a qualitative, not as a quantitative test. If a reducing action on this agent is manifest, the water is to be suspected, though not condemned, unless the suspicion is confirmed by other tests. If the permanganate is not reduced there is but little to fear from the organic matter.

I subjoin details of the analyses :—

TERLING WATERS.	1 Middle-ditch.	2 School.	3 Lines.	4 Terling Place.
Colour in 2ft. tube	Greenish yellow.		Greenish yellow.	
Sediment	Consid. brown.	Clear, a few flakes	Distinct brown.	Clear, a few flakes
Odour	None perceptible when warmed.			
Taste	None perceptible.			
Hardness before boiling	25°·6	24°·8	18°·2	15°·3
Do. after boiling 1 hour	16°·5	4°·6	17°·4	7°·2
Total solids in grs. per Imperial gallon	51·9	27·1	38·6	25·7
Fixed salts	50·3	25·6	36·2	23·2
Volatile and combustible	1·6	1·5	2·4	2·5
Nitric Acid	6·67	Trace.	2·56	3·05
Ammonia	0·04	None	Traces.	None.
Action on permanganate of potash	Considerable.	Very little.	Considerable.	Little.
Cubic inch of gas per gallon	22·82	15·0	9·0	12·0
Consisting of Carbonic acid	9·57	6·35	3·6	6·00
Consisting of Oxygen	3·08	2·31	0·9	1·38
Consisting of Nitrogen	10·17	6·34	4·5	4·62
Ratio of O:N	1:3·3	1:2·75	1:5	1:3·3

SECOND REPORT (Feb. 4th, 1868.)

Present state of epidemic.

On the 29th of January, in accordance with renewed instructions, I returned to Terling to report again on the state of the epidemic and to ascertain what steps were being taken by the authorities to ensure the abatement of the disease. I found that new cases of fever had continued to arise since my last visit, and that up to the 31st of January at least 260 cases had occurred; the women and children were no longer the principal victims, for many of the able-bodied men and boys were now suffering from the fever. Almost all of these having relatives ill, were exposed to poisonous influences, and the necessarily contaminated state of the atmosphere would easily account for the disease amongst the remainder. The entire number of deaths up to this date was 28, but it is to be feared that others will yet succumb to the disorder. At the same time I am glad to be able to report that the epidemic seems now to have begun to decrease for since the 26th of January only one person has been attacked,

and Dr. Gimson of opinion that the more recent cases are of a decidedly milder type than those with which the epidemic commenced.

Notwithstanding that the urgency of very immediate and prompt action had been again and again pressed upon the Board of Guardians, I still found abominable nuisances in Terling, and it is hardly possible to speak in sufficiently strong terms of the culpable neglect shown by that authority. Fortunately the vestry of the parish (the Sewer Authority), acting under Sec. 11. of the Sanitary Act 1866, had in three of the most populous parts of the village provided a pure water supply for the inhabitants; but to give an example of the mode in which the Board omitted to perform their ordinary duties, even when the villagers were dying around them, I would call attention to a nuisance of colossal magnitude situated behind some cottages on the Upper Green. Within about ten or twelve feet of the back doors and windows of the cottages in question, is a large ditch in one place nearly two yards broad, full of stagnant fluid. Over this ditch four wooden privies are placed, and their entire contents fall into it; the floor in one of them is nearly broken away. All the slops from these cottages are also poured into the ditch, and for a space of between fifty and sixty yards, a foul urinous fluid with fæcal matter floating on its surface, lay soaking into the porous soil on which the cottages are built, and emitting a stench which I, in common with two companions easily detected at a distance of 100 yards. This abominable nuisance has been the subject of much discussion; twice I formally brought it under the notice of the Board, and on two occasions I pointed it out to the officers of the authorities, especially on account of the existence of fever in the adjoining cottages, but, unfortunately, on the 29th of January it was in the same state as when I first drew attention to it. Evidently the main object at which this local authority has aimed is not so much to remove with an exemplary haste all possible sources of disease in Terling, as to give the public an impression that it has already done so; whereas, in reality, the present sanitary condition of the village would be disgraceful, even if this vast epidemic had not rooted itself so deeply on the spot. In no single instance could I ascertain that the Board of Guardians had been instrumental in causing a properly constructed cesspool to be made.

Neglect of duty on the part of the nuisance authority.

Fortunately for the villagers immense private efforts have been made for their relief. Terling Place has been, to use the expression of an inhabitant, "an open house"; wine, brandy, beef tea, milk, and luxuries have been liberally supplied from that residence, and Dr. Gimson who has without official obligation, given up almost all his time in attending to the sick, informed me that, at Lord and Lady Rayleigh's expense, the poor were provided with every requisite, and had their linen washed for them. In addition to this, as the Nuisance Authority had made no attempt to remedy the overcrowding, Lord Rayleigh had fitted up the village school as a convalescent hospital for children; these were brought to it in a covered waggon, and on their arrival they were stripped and washed, then entirely reclothed with garments provided by private individuals, and placed under the care of a lady nurse. Sisters from St. Magaret's Home, East Grinstead, were superintending the nursing throughout the village, and spending their nights with the most dangerous cases.

Relief from private sources.

It is to be hoped that the experience which has in Terling been so dearly bought will not be without effect on the future administration of sanitary law in this district. Measures should at once be adopted which will in future years prevent so devastating an outbreak of disease; the

whole system of cottage accommodation requires re-modelling, and, above all, the cottages should be periodically inspected by a competent person, in order to prevent the unrestricted flourishing of nuisances around the dwellings.

I was also instructed to ascertain, before concluding my visit, whether the other towns and villages belonging to the Witham Union were in a similar insanitary condition to that in which I found Terling, and with this view I spent a few hours in Witham, Great Coggeshall, Messing, and Hatfield Peveril.

Sanitary condition of Witham.

Witham is a small town, containing about 3,500 inhabitants, and is the only place in this Union which is governed by a Local Board of Health. The main streets have an appearance of great cleanliness and comfort, but on passing from them into courts and slums which are hidden from the general view; cesspools, dilapidated privies, with their contents running about the yards and gardens, heaps of decaying animal and vegetable matter, and every species of nuisance can be found in abundance. Some of the inhabitants live in hovels of the most miserable description, where they are surrounded by intolerable stenches, and, I was informed that they dare not complain to their landlords or to the Inspector of Nuisances of the filthiness around them, for if they go to the former, they fear that he will turn them out of their houses, whereas the latter is the relieving officer, and it is their belief that any complaints made to him would go far to prevent their receiving parish relief. But a more serious obstacle even than this exists to any sanitary improvement. Many of the properties on which the worst nuisances exist belong to members of the Local Board, and I would especially allude to several groups of cottages belonging to a Mr. Tomasin, the stinking nuisances around which render them unfit for human habitation. Mr. Tomasin is a gentleman of large fortune, he has a seat at the Local Board, and yet, so much has he neglected the dwellings of the poor which belong to him, that the magistrates have been compelled to summon him before them, in order to force him to remove nuisances on his cottage property. In this town there is, as a rule, a common water supply for several cottages, and the wells are generally protected from contaminating influences. Witham has no system of drainage, but in all probability one will before long be constructed. It is an unhealthy town, and though there has been no special prevalence of specific fevers, still I am informed that disease here assumes a low type, and that strumous affections, rickets and phthisis, attack a large number of the inhabitants.

Sanitary condition of Great Coggeshall.

Great Coggeshall is a small town of about 3,680 inhabitants, and though in a considerably better sanitary state than either Terling or Witham, many portions of it are in a very dirty condition. The inhabitants consist principally of weavers, and, owing to great depression in the trade, they are mostly in a very destitute state. I found no open cesspools in the place, and the privies are periodically inspected and emptied, but ashes, slops, and filth, are generally thrown indiscriminately about the courts and yards. Five years ago about 200 cases of scarlet fever, and 30 deaths took place; and the parish doctor informed me that last year nearly 100 cases of smallpox occurred in the town. The water supply seemed pure, the larger portion of the town being supplied from a public well, called St. Peter's Well, the water from which is conveyed by means of pipes to open reservoirs and pumps in the most populous districts.

Sanitary condition of Messing.

Messing is a small village, containing rather over 800 inhabitants, and may be considered now to be in a moderately good sanitary condition.

This state is, however, only due to a severe outbreak of "fever" which occurred four years ago, and which caused, as I was informed, as many as 23 deaths; nuisances were then rapidly cleared away, privy accommodation was improved, and many of the wells were closed. The inhabitants now procure their drinking water from pumps giving a pure supply.

Sanitary condition of Hatfield Peveril.

Hatfield Peveril, the last village which I visited, and which contains about 1,310 inhabitants, has up to the last few weeks been in a disgraceful sanitary condition; a committee has, however, since the outbreak of the epidemic in Terling, been appointed to improve its state, and this step has been taken none too early, for typhoid fever a few years ago prevailed very extensively amongst the inhabitants, and from personal observation I can say that, up to a very recent date all the predisposing causes of that disease existed abundantly in the village, and that the exciting cause was alone required to produce another outbreak. Here as in the other portions of this district it will be seen that proper sanitary measures have been neglected, until the prevalence of some fearful disease has awakened the authorities to a sense of their duty.

State of surface water throughout the Witham Union.

It is interesting to note that the sudden rise in the surface-water which seemed so clearly to bear upon the outbreak of typhoid fever in Terling, had not been noticed in any of the other portions of the Witham Union which I visited, and in which I did not find that there had been any scarcity of water during the summer and autumn of last year. The absence in these places of the undulations of the surface, so common in Terling, may have some effect in causing this difference, so also may the difference of the superficial soils; thus, at least in some parts of Great Coggeshall only about two or three feet of gravel lie over a yellow clay, locally called Loom, and at all times of the year an abundance of water can be found in this gravel; St. Peter's Well, which supplies so large a portion of the town, is only between two and three feet deep. Thus that which overwhelming evidence has compelled me to consider as of the greatest importance in the vast but isolated outbreak of typhoid fever in Terling, I find has been confined to that village, and has not existed generally throughout the uninfected districts.

POSTSCRIPT: (March 10th, 1868.)—According to information received since writing the above reports, I am able to state that the epidemic has almost entirely subsided, only one or two fresh cases having occurred during each of the last two weeks. The number of deaths up to March 7th was 41; the anual death-rate being 16.

A communication which I have received from the Rev. F. T. Hill, vicar of Terling, is of considerable interest because it affords additional proof that the well water has been the cause of the outbreak. He informs me that on the outskirts of the village there are 71 persons who procure their drinking water from ponds. Only six cases of typhoid fever have occurred amongst them, and of this number four had been in the habit of frequenting the village; three being children who attended the village school, and the fourth, a man who had been temporarily engaged there as a carpenter.

No. 5.—REPORT by Dr. BUCHANAN on the DISTRIBUTION of PHTHISIS as affected by DAMPNESS of SOIL.

N.B. The Maps illustrating this Report are at the end of the Volume.

THE general sanitary inquiry which was entrusted to me last year having appeared to show a relation between wetness of soil and prevalence of consumption, the subject is now further examined with direct reference to geological considerations. The results obtained from this new basis of inquiry turn out to be definite and confirmatory of the conclusions provisionally arrived at last year.

Materials for inquiry.

The Geological Survey of England, advancing to completeness in its records of the great formations of the country, has hitherto mapped the minute surface geology only in the counties of Surrey, Kent, and Sussex. From the present point of view it is plain that surface peculiarities must be taken into account quite as much as the great divisions of the geologist—that brick earth, drift gravel, river alluvium, and the like, have an importance in themselves apart from the character of the larger formations over which they lie. The three south-eastern counties, therefore, form the only area where the Survey yet affords materials for profitable detailed examination of soil as affecting the health of residents on it; and the present report will concern itself exclusively with them.* It happens that there is no part of England better adapted to the enquiry—in which varieties of soil would be greater, and differences of other sorts less obtrusive.

The materials for the present report have been (1) the Parliamentary Return, No. 12, Session 1863, which furnishes for each registration district the death-rate from consumption in the mean of the 10 years 1851–60; (2) local inquiries that were necessary to correct the registered death-rates of particular districts; (3) the census returns of 1841–51–61; (4) the maps of the tithe survey, which give the boundaries of the several parishes comprised in each registration district; (5) the maps of the Geological Survey, with various unpublished sections and other documents placed at the disposal of this report by the Director-General; and (6) minute information about the topography and geology of particular districts supplied by Mr. Whitaker and Mr. Topley, two of the geologists who have actually worked the three counties under examination; and (7) information from medical practitioners, surveyors, and others on local peculiarities of soil or population, and on various conditions affecting the prevalence of consumption.

The above statement makes evident the wide obligations under which the report lies for assistance in the several points investigated. Primarily to Sir R. I. Murchison, Director-General of the Geological Survey, to Professor Ramsay, Director, and to other members of the Survey. To Messrs. Whitaker and Topley thanks are due for the summary statement of the general characters of different geological formations, and for valuable aid in revising the accounts of local geology. Dr. Balfour and other officers of the army and navy medical departments, the directors of convict prisons, the superintendents of lunatic asylums, and the medical officers of hospitals have kindly given themselves labour to enable correction to be made in the registered mortality

* There are, it is true, parts of other counties where the Drift has been mapped by the Survey; but it has not been possible to regard small and divided areas with any advantage.

APPENDIX.

No. 5.
On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.

Plan of inquiry.

of districts. Among the medical practitioners who have rendered such assistance, and who can only be thanked collectively here, Dr. Greenhill, of Hastings, and Mr. Reid, of Canterbury, must be specially mentioned.

Fifty-eight registration districts,* being all those of the three south-eastern counties (with the exception of such as lie in the metropolitan area) have been brought under detailed examination. They were considered in two chief ways: first, as to the true consumption rate of their population, with attention to other conditions besides that of soil likely to influence this rate; and, secondly, as to the numbers of population in each district living upon various kinds of soil under various topographical conditions. The results of the two sorts of investigation were then brought together, and, as far as practicable, summary statistical conclusions have been drawn from them.

A. Consumption in districts.

THE statistical inquiry into the amount of consumption in each district was surrounded by various difficulties, which have been laboriously attacked, but have not in every instance been satisfactorily overcome. Conditions whose influence has been examined and more or less successfully allowed for are—(1) rapidly increasing population and varying rate of increase, a consideration which has required the re-calculation of many figures in the parliamentary return; (2) the inclusion of much consumption with other diseases of the lungs, which has presumably taken place in certain districts; (3) the influence of hospitals and other public institutions in increasing the mortality from consumption of the districts in which they are situated; (4) the use of particular places as resorts for consumptive invalids; (5) the special circumstances of large bodies of the male population, particularly in camps and dockyards.

In addition to making corrections and allowances of this nature it has been wished to consider other conditions influencing the local amount of consumption; such, for instance, as the urban or rural character of the population, riches or poverty; varying occupations (beyond those that have been specified); race, habits, and lodgment of people; the prevalence of intermittents; atmospherical conditions other than those due to varieties of soil. But while certain of these influences have been here and there considered, a thorough examination of them has not been possible, and their effect upon phthisis turns out, at the end of the enquiry, to be wholly thrown into the shade by the larger influence of soil.

In the following table the 58 districts are arranged in the order of their death-rate from consumption. Persons between the ages of 15 and 55 have alone been considered, and the mean of the death-rates of the two sexes is that which has primarily determined the position of districts on the table. But where the male rate was obviously subjected to disturbing influences from which the female rate was com-

* These districts, arranged upon principles that only the antiquary can by any chance comprehend, have no general relation to any natural divisions of country, and absolutely none whatever to any geological feature. The first inclination of an inquirer into the effect of geology upon disease is therefore to discard the artificial division into districts altogether, and, having mapped out several localities with broadly distinguished geological features, to investigate the amount of disease prevailing in each, by examination of the death records and other data of localities so mapped out. It is to be hoped that inquiry on this basis may yet be made, and the conclusions of this report will have done more than immediate service if they encourage to the extended observation in the future of disease in relation to geology. But for a single observer, with limited time at his disposal, the collection and analysis of disease statistics from original documents for a series of years, and for an area large enough to give valid general results, was soon seen to be impossible.

Registration Districts in the Order of their proper Mortality from Consumption.

Annual Death-rate registered from all Causes in both Sexes at all Ages.	Districts numbered according to their order.	Registered Phthisis Death Rate, 15-55.		Registered Phthisis + Lung Disease Death Rate, 15-55.		Notes, with corrections of the Phthisis columns for Hospitals, &c. Where correction is not made, it may be assumed that the registered rates are little affected by Institutions.
		Mean of Two Sexes.	Females.	Mean of Two Sexes.	Females.	
1766	3. Dartford	261	263	325	312	(a) Of Elham, the male rate being of no value, 10 has been subtracted from the female rate for the approximative true mean, 313.
1620	4. Epsom	277	291	366	369	
2073	5. Milton	276	330	378	363	
1656	6. Godstone	282	323	361	395	
2044	7. North Aylesford	289	306	383	375	(b) The rates of Bridge become 342 mean and 425 female, if corrected for Canterbury Hospital.
1986	9. Dover	296	289	368	335	
1620	10. Bromley	294	303	348	351	
1597	11. Steyning	295	304	363	354	(c) Gravesend has been classed by its female rate as being more trustworthy than the mean.
1802	12. Chertsey	296	325	384	396	
1856	13. Croydon	303	275	385	334	
1693	15. Cranbrook	311	381	375	446	(d) The rates of Eastbourne might, perhaps, be taken as slightly smaller, in consideration of some invalid visitors.
1989	16. Richmond	313	251	407	330	
1791	17. Kingston	315	279	423	370	
1758	18. Elham (a)	277	323	344	382	
1830	19. Blean	315	344	381	418	(e) Registered male rate of Farnham being of no value, 10 has been subtracted from the female rate for the approximative true mean, 339.
1816	20. Bridge (b)	331	418	399	461	
2265	21. Gravesend (c)	405	331	546	435	
1732	22. East Grinstead	333	363	402	412	
1718	24. Reigate	337	352	403	409	(f) At Battle, correction for obvious inclusion of much phthisis in registered lung disease brings phthisis rates to 344 mean and 398 female.
1666	25. Eastbourne (d)	336	392	382	416	
1733	26. Farnham (e)	292	349	373	405	
1701	28. Hambledon	343	411	432	506	
1703	29. Battle (f)	294	338	414	474	(g) For Canterbury, deduction for hospital patients brought from other districts makes true mean rate 348 and female rate 298.
2288	30. Canterbury (g)	384	328	529	445	
1867	32. Hollingbourne	352	394	417	460	
1925	33. Malling	356	423	423	489	
1843	34. East Ashford	359	456	374	540	(h) For Farnborough, the registered male rate being of no value, 10 has been subtracted from the femal rate for the approximative true mean 371.
1781	35. Sevenoaks	361	427	426	487	
1912	36. Guildford	369	379	394	433	
1426	37. Farnborough (h)	291	381	352	429	
1946	38. Eastry	371	385	445	438	(i) In Maidstone, deduction for deaths in lunatic asylum patients brought from other districts makes true mean rate 379 and true female rate 405.
1967	39. Faversham	370	429	449	490	
1988	40. Rye	371	438	468	501	
2265	42. Maidstone (i)	434	475	546	577	

REGISTRATION DISTRICTS, &c.—*continued.*

Annual Death-rate registered from all Causes in both Sexes at all Ages.	Districts numbered according to their order.	Registered Phthisis Death Rate, 15–55.		Registered Phthisis + Lung Disease Death Rate, 15–55.		Notes, with corrections of the Phthisis columns for Hospitals, &c. Where correction is not made, it may be assumed that the registered rates are little affected by Institutions.
		Mean of Two Sexes.	Females.	Mean of Two Sexes.	Females.	
1755	43. Cuckfield - -	387	471	435	517	(*j*) At Worthing the rate should perhaps be taken as somewhat smaller, in consideration of some invalid visitors.
1733	44. Dorking - -	399	478	451	510	
1894	45. Uckfield - -	398	484	443	507	
1747	46. Hailsham - -	392	535	439	609	
1919	47. Ticehurst - - -	401	457	462	503	
1790	48. Worthing (*j*) -	419	445	465	479	(*k*) In Lewes, correction for hospital and prison brings the true rate to 426 mean and 464 females.
1982	49. West Ashford -	421	542	489	612	
1947	50. Lewes (*k*) - -	502	508	575	549	
1931	51. Tenterden - -	435	528	486	579	
1765	52. Horsham - -	440	518	495	575	(*l*) The rates of Westhamptnett become 449 mean and 521 female, if corrected for Chichester Hospital.
1813	53. Westhamptnett (*l*)	441	518	490	557	
1818	54. Midhurst - -	455	539	511	597	
1824	55. Thakeham - -	454	560	497	605	
1855	56. Petworth - -	462	509	512	553	(*m*) At Chichester, deduction for hospital deaths in patients from other districts brings the rates to 536 mean and 450 female rate.
1748	57. Westbourne -	498	610	552	651	
2121	58. Chichester (*m*) -	566	463	651	539	
1934	1. Sheppey -	202	251	281	311	Population of Sheppey special and migratory; its true death-rate uncertain.
1817	2. Hastings -	498	466	588	526	At Hastings more than half phthisis deaths are invalid visitors, approximately true rates taken at half those registered.
2108	8. Thanet - -	392	364	459	415	In Thanet, deduction for visitor invalids gives as truer rates, 292 mean and 264 female phthisis.
2489	14. Hoo - - -	301	376	380	421	The population of Hoo is so small that a very few deaths more or less would entirely alter the registered rates.
2024	23. Tunbridge -	399	437	477	503	For Tunbridge, rough deduction for visitor invalids gives as truer rates, 333 mean and 364 female rate.
2310	27. Medway - -	480	353	624	440	The male rate of Medway being of no value, 10 has been subtracted from the female rate for an approximative true mean, 343; but the exact place of the district is open to several doubts.
2141	31. Romney Marsh -	348	381	429	447	Romney Marsh is affected like Hoo, and in other ways.
2200	41. Brighton - -	435	372	515	434	The true place of Brighton in the series is wholly unknown.

paratively free, the position of a district on the table has been determined by the latter rate; and where disturbing conditions have been eliminated in a district, the position given to it below is determined by the corrected, and not by the registered, rate of mortality. Eight districts, the order of which among other districts is more uncertain, have been placed by themselves at the foot of the table, with however the numbers attached to them that signify their probable position among the rest. The entire population that has furnished the materials for this table amounts to 1,118,372, living on 3,812 square miles.

B. Geology of districts.

NEXT to this examination of the amount of phthisis in each registration district, the geology of these areas has been taken up. For each district an examination has been made, as carefully as the conditions of the enquiry has permitted, into the character of the soil on which the population live. In this investigation the dip of the beds, the elevation and slope of the surface, and generally the water-holding (with some other) qualities of the ground, have been regarded as well as the geological formations that entered into the structure of the district. A prefatory account of the lithological character and usual features of the various formations has been contributed to this report by Messrs. Whitaker and Topley.

Formations comprised.

The geological formations that occur in the counties of Surrey, Kent, and Sussex* are shown in the following list:—

- Recent
  - Alluvium.
  - Blown Sand.
  - Shingle.
- Post-Tertiary
  - Brick-earth.
  - Gravel and Sand.
- Tertiary
  - Bagshot Beds
    - Upper Bagshot Sand.
    - Bracklesham Beds (Middle Bagshot).
    - Lower Bagshot Sand.
  - London Clay.
  - Lower London Tertiaries.
    - Oldhaven Beds.
    - Woolwich and Reading Beds.
    - Thanet Beds.
- Upper Cretaceous
  - Chalk
    - Chalk with flints.
    - Chalk without flints.
    - Chalk Marl.
  - Upper Greensand.
  - Gault.
- Lower Cretaceous
  - Lower Greensand
    - Folkestone Beds.
    - Sandgate Beds.
    - Hythe Beds.
    - Atherfield Clay.
  - Weald Clay.
  - Hastings Beds
    - Upper Tunbridge Wells Sand.
    - Grinstead Clay.
    - Lower Tunbridge Wells Sand.
    - Wadhurst Clay.
    - Ashdown Sand.
    - Ashburnham Beds.

* See Geological Survey, maps 1, 2, 3, 4, 5, 6, 7, 8, 9, and 11; and sections.

Alluvium. The deposit, fringing and formed by streams, consists of clay, silt, and peat, with here and there more sandy beds. By the sea there is sometimes little else than sand with sea-shells, as at Deal. It forms only tracts of marsh land, more or less subject to floods, and often below ordinary high-water mark.—*Blown Sand* consists of loose sand driven inland by the wind, and disposed in the form of irregular hillocks, constantly liable to further shifting until protected by vegetation.—*Shingle* is often banked up by the waves to some height above high-water mark, forming either a long narrow flat as at Deal, or a succession of ridges and furrows as at Romney Marsh. In the south-eastern counties the shingle consists of flint pebbles in various stages of wear. So firm and well packed is the mass of pebbles that houses are often built direct on the shingle, levelled and slightly covered with concrete.

Brick-earth here includes the loamy matter brought down by rain in districts formed by soft rocks (clay, sand, &c.); the similar deposit that sometimes caps the gravel on the terraces or gently sloping flanks of river valleys; and some of the surface beds of the Chalk district may come under the same head. Brick-earth is a mixture of clay and sand in varying proportions, but must be classed with clays rather than sands in its permeability. Like the gravel that commonly underlies it, the brick-earth of the valleys (whether on terrace or at bottom) has an even surface.—*Gravel* (and *sand*). The gravel in these counties is for the most part made up of flints from the chalk, more or less worn; and with these much sand is mixed. Tracts of gravel occur at various levels along wide valleys, and though of no great thickness they give rise to marked features in the surface of the ground, forming broad dry plains or terraces, cut through in parts by side valleys. These form outlets for the water that sinks through the gravel, and when they reach down to the beds below often have springs along their flanks.

Surface-beds of various ages on the Chalk. On the higher parts of broad chalk-tracts there is often a most irregular capping of "clay-with-flints," a brown clay crowded with unworn flints, which greatly alters the nature of the district where it occurs, forming a stiff soil, and a country which is more or less wooded instead of the open downs common with bare chalk. With this clay there is sometimes a little brick-earth.—In Kent and Surrey there are also a few patches of sand near the chalk-escarpment, the geological age of which is not certainly known. —But on none of these beds is there any noteworthy population.

BAGSHOT BEDS. This series as a whole is permeable, being chiefly sand, and it forms in the London Basin a large tract rising to fair heights with pretty sharp slopes, not much inhabited except at Aldershot Camp. The *Upper Bagshot Sand* is a thick mass of sand which forms ridges of dry barren land, in great part capped by gravel.—The *Bracklesham Beds* are the most impervious of the series, consisting of alternations of clay, sand, and loam, about 50 feet thick in the London Basin. Here they crop out on the flanks of hills or bottoms of valleys, throwing out water from the sands above, and forming a damp soil. But at Selsea Bill they make a broad low tract much covered by gravel. —The *Lower Bagshot Sand* is light coloured, here and there clayey, passing downwards into the London clay, the junction with which is more or less wet. This division reaches a thickness of 150 feet, and rises into hills.

LONDON CLAY is a thick uniform mass of dark, tough, impermeable clay; but the few lowest and the few highest feet of it may be somewhat sandy. Where not covered by gravel, this clay forms a broad undulating tract often ending with a fairly marked escarpment that rises to a notable height, though lower and far more gently sloping than the

scarp of the Chalk. It rarely forms a plain like that of the Weald Clay. When covered by gravel, flattish plains are formed (as before stated), the drainage of which is determined by their height.

LOWER LONDON TERTIARIES. This series was once called "plastic clay," a misleading name, inasmuch as plastic clay only occurs in the middle division of it, and not always there. The broad northern tract (near London) is almost wholly of sand and pervious.—The *Oldhaven Beds* are a set of fine sand and pebble beds that occur in Kent, and stretch a few miles into Surrey. On the west the pebble beds are generally in great excess, and form dry level plains (Blackheath, Bexley Heath, Bromley, &c.), at a fair height, mostly ending off with sharp slopes, and sometimes cut through by small valleys. In East Kent, on the other hand, this series consists almost wholly of sand, and crops out on the flank or at the bottom of London Clay hills.—*Woolwich and Reading Beds.* This thin series presents perhaps more varieties of character than any other in the district under consideration. In its narrow outcrop in Surrey it consists of irregular alternations of sand and mottled plastic clay; towards the eastern part of Surrey, and in the western part of Kent, it consists of sands, loams, laminated clays with shells, and pebbly sand. In East Kent it is represented by coarsish sand. On the south of the Wealden district, sand and plastic clay again occur. These irregular beds rarely make any conspicuous feature in the form of the ground.—The *Thanet Beds* are nearly as local as the Oldhaven beds. They are found only in the north, and thin out westward near Leatherhead. In Surrey and West Kent they consist of fine loamy sand, increasing in thickness eastwards. In East Kent they get still thicker (to 80 feet or more) and also more clayey, until at last more than half consists of a sandy marl. The Thanet Beds mostly form low gentle slopes, sometimes stretching out into the Chalk district to a greater height.

CHALK. The greater part of the Chalk contains beds of flints, mostly in the form of irregular-shaped nodules, but sometimes as continuous layers. The Lower Chalk, however, is without flints, but both divisions are jointed and allow of the passage of water from the surface. The lowest part, the Chalk Marl, is more clayey than the rest, and sometimes causes springs at its outcrop. The Chalk forms a succession of hills and valleys, and ends off towards the Weald with a sharply-sloping escarpment, generally the highest ground of the district, but cut through by the rivers. The level of the Chalk-country falls, with the dip, from the escarpment, and the tops of the hills are in a gently-sloping plane: the features indeed being those of an inclined table-land cut through by valleys. From its sharp slopes and permeability chalk has a dry soil.

UPPER GREENSAND and GAULT. *Upper Greensand* is not always present, and has never any great thickness. It consists of a more or less clayey greensand with soft sandstone below: it has but a narrow outcrop and makes no great feature at the surface, forming merely a low ridge between the Chalk and Gault, or being merged in the Chalk escarpment. The junction with the Gault is apt to have springs, and the formation generally is plentifully supplied with water, though not of necessity water-logged at its outcrop.—The *Gault* is a stiff blue clay, 100 feet or more thick, also with a narrow outcrop, usually placed at the bottom of a sort of valley dividing the Chalk ridge from the slope of Lower Greensand. It is seldom much built on.

LOWER GREENSAND. On the north of the Wealden area this formation makes a broad tract of high ground, rising from the Gault and ending towards the Weald by a sharp escarpment. On the south, however, its

outcrop is narrower, and forms lower and less hilly ground.—The *Folkestone Beds* consist almost wholly of sand rising up into hills from beneath the Gault, and forming a dry country.—The *Sandgate Beds* are more clayey, consisting of loam and sandy clay, with sometimes fuller's earth. Their outcrop is generally in a slight hollow, and they often throw out water from the sand above.—The *Hythe Beds* are the most important part of the Lower Greensand in Kent and Surrey. In Kent they are known as Kentish Rag, an alternation of beds of more or less cherty limestone and soft crumbling calcareous sandstone; and in Surrey they include the calcareous sandstone known as Bargate stone. In other places the Hythe Beds consist of sand and sandstone, and they are everywhere pervious. They rise to a good height and end off towards the Weald with a sharp escarpment.—The *Atherfield Clay* is the lowest member of the Lower Greensand, but as it is merely a few feet of stiff clay, it has been taken with the Weald Clay for the purposes of the present inquiry.

WEALD CLAY. This is a great mass of clay and shale, 600 feet thick, with occasional thin layers of shelly limestone, calcareous sandstone, and ironstone. In the neighbourhood of Horsham there is a thicker but local bed of sandstone and calcareous grit alternating with clay, in all about 10 feet thick. The lowest part of the Weald Clay is often sandy. This formation does not reach any great height except where it rises up to the sharp escarpment of the Lower Greensand, or where outliers of it occur on the high tracts of the Hastings Beds; but it forms a broad flattish vale, with only a few low hills, and it has often cappings of gravel along the streams that wander through it.

The HASTINGS BEDS consist of alternations of sand and clay, the former predominating, so much so that the whole series has been termed "Hastings Sand." * They rise from below the Weald Clay flat, and form undulating ground. The lower beds occur mostly towards the middle of the Wealden area, and form high land, their dip being greater than the slope of the ground; but they are frequently brought up by faults and folds in other places. This mode of occurrence renders it difficult to describe the features of the districts, except in very general terms.—The *Tunbridge Wells Sand* consists, on the east, of a mass of fine sand and soft sandstone, with thin beds of loam and clay, and altogether is about 150 feet thick. On the west it is divided into two parts by a local bed of stiff (Grinstead) clay, the thickness of the Upper Sand being about 100 feet, of the Grinstead Clay up to 60 feet, and of the Lower Sand about 60 feet.—The *Wadhurst Clay* is a stiff clay or shale, with sometimes a little stone, and is seldom less than 100 feet in thickness.—The *Ashdown Sand* is like the Tunbridge Wells Sand, but is nowhere divided by any thick mass of clay.—The *Ashburnham Beds* do not crop out to the surface over any large area. They consist near Hastings of mottled clays, with layers of sandstone; but near Battle and Brightling of clays, shales, and sandstones, with many beds of limestone. As a whole, they form a rather retentive soil, but much less so than Weald Clay or Wadhurst Clay.

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* F. DREW. "On the succession of beds in the 'Hastings Sand.'" *Quart. Journ. Geol. Soc.*, vol. xvii., p. 271 (1861). P. 285. "Of the sandy beds there is "more to be said. The sand itself is nearly always extremely fine, almost an im-"palpable sand. On this account it bears itself somewhat in the same way that "clay does as regards the presence of water; instead of absorbing it like an ordinary "sand, it becomes a pasty mass that can be moulded like a very light clay, and this "though it contains no alumina." P. 286. "Loam occurs in large quantities in the "sandy beds."

THE 58 registration districts of the south-eastern counties are described below in the order in which they appear on the table (page 97) which shows their relative death-rates from consumption. For each district is shown (1) the acreage and population; (2) the general geological and topographical features; (3) the character of the formations and soils upon which its chief towns and villages are placed; (4) the numbers, as nearly as can be judged, of the residents upon each description of soil; then the registered phthisis rate for males and for females is given, and the account ends by stating any circumstances that may cause the true rate to differ from that which is registered, and by making such allowance for these as is possible.*

Geology and consumption of districts in order of previous table.

[3.] DARTFORD, Kent. Acres, 53,109. Population, 32,316. Maps 1 and 6.

Dartford.

Is geologically in two portions, the southern of Chalk with surface clay, sloping downwards from south to north; the northern is the main of Tertiary Beds, consisting on the west of a mass of Lower London Tertiaries, with a little London Clay, and on the east of outliers of the same over chalk. Over both portions of this northern district there are deposits of brick-earth and drift gravel. The north-western or Tertiary district consist of London Clay, scarcely at all inhabited; a broad tract of sandy pebble-beds, with Woolwich and Thanet Beds below them. The pebble-beds, on which great part of the population lives, have a level surface cut through by valleys, and are mostly pervious, and vary from 10–50 feet in thickness. The beds below are somewhat less pervious, but are only impervious where the clay shell-beds of the Woolwich series occur, and they crop out upon slopes. Very few people live upon impervious soil. The whole district is divided by the valley of the Darent, and on the north-west it is also cut into by the valley of the Cray. The marshes bordering the Thames are uninhabited.

Dartford lies in the valley of the Darent and on the slopes of the valley. About a third of the town is on alluvium, flat and at low level, and it must be wet. The rest is on gravel over chalk, and on bare chalk, at a higher level and quite dry.

A great number of the villages of this district are situated along the Darent valley. Of these *Wilmington* is on thin beds of gravel, brick-earth, and Thanet Sands overlying chalk, on a rise and in a dry situation. *Sutton Darent, Eynesford, Horton Kirby,* and *Farningham* are on local gravels and on chalk, bordering the river; parts of them may have wet soil, but in the main lie so as to be quite dry. *Crayford, Erith,* and *Bexley,* with parts around them, stand on various gravels and sands, and upon chalk. Portions of them are rather low but upon dry slopes. Parts of *Bexley* and *Crayford,* however, are on alluvium. Besides outlying villages on bare chalk, *Swanscombe, Southfleet,* and other places

* The number in brackets prefixed to the name of each district indicates the position in which the district stands among the 58 districts examined, in respect of its phthisis death-rate. Table, p. 59. The map references are to the one-inch maps of the Geological Survey, which bear the same numbers as the Ordnance maps of the same scale. Population, unless where otherwise stated, is that of the census of 1861.—The names of places here signify the town or village that is commonly so known, and not the parish of the name, which often stretches far away, and includes other places, or else does not include the whole of the town. Minute details of each whole parish were of course taken into consideration in forming the numerical statement subjoined to each district. The phthisis rate shows the male and female deaths annually (1851-61) occurring between the ages of 15–55, per 100,000 males and per 100,000 females living at that age in each district.

are on Tertiary outliers (Thanet Sands and drift gravels); at Swanscombe there is clay. Greenhithe and Stone lie on chalk, bordering the Thames, not many feet above high-water mark. Several places of less size are on the pebble-beds and other parts of the Lower London Tertiaries.

Approximate number of population resident on alluvium, 2,700; on uncovered London Clay, 100; on Lower London Tertiaries, 13,580; on Chalk, 15,483; and on board vessels, 453.

Phthisis death-rate for males	- -	260
" " females	- -	263.

[4.] EPSOM, Surrey. Acres, 41,180. Population, 22,409. Map 8.

Epsom.

The northern half of this district consists of Tertiaries and the southern half of Chalk, the towns and villages being mainly at the junction of the two formations.

In a line across the district, *Great* and *Little Bookham, Fetcham, Leatherhead, Ashtead, Epsom, Ewell, Cheam, Sutton,* and *Carshalton* are situated on this junction of the tertiaries with the chalk, the position having evidently been chosen for facility of procuring water. The inhabited parts of these places range from the London Clay across the Woolwich and Reading Beds and some Thanet Sand to the chalk. Some have patches of gravel over the other formations. The chalk near these towns and villages rises to the south with a fair slope, and must be pretty full of water near its junction with the tertiaries.

The surface slope of the tertiaries northward from their junction with the chalk is sometimes upwards, sometimes downwards, the latter chiefly where the country is intersected by valleys. But the dip of the beds is northerly, so that, in so far as they are pervious and not below the level of the waterline in the chalk, water can get away by them. But these tertiary beds are mostly impervious for some part of their thickness, and the level of saturation would (in the absence of side valleys) soon be reached below the surface.

Whether the soil is damp or dry depends upon minute local circumstances that affect the saturation level. This ranges probably from a very few feet to 50 or thereabouts. At Epsom, before drainage works, there were places where water overflowed the surface on a well being dug; there are of late years few places that have water so near the surface as 5–6 feet.

On the west this district is drained by the Mole, on the east by the Wandle, and between these rivers by the Hogs-mill and another stream.

Cobham and *Stoke D'Abernon* are on gravel underlain by London clay and surrounded by alluvium. *Banstead* is on an outlier of Thanet Sand (with irregular deposits of clay) over the chalk.

Approximate number of residents on London Clay with gravel, 2,409, without gravel, 3,000; on Lower London Tertiaries, 8,500, some of whom live on impervious beds; and on Chalk, 8,500.

Phthisis death-rate for males	- -	264
" " females	- -	291.

[5.] MILTON, Kent. Acres, 35,409. Population, 14,775. Maps 3 and 6.

Milton.

This district has a general slope downwards from south to north, with valleys and ridges running more or less in the same direction. The road from Chatham to Canterbury through the district gives a good notion of the varieties of level. This ranges from 140 feet about Rainham to 99 at Newington, then rises to 170 feet, and near Milton is

only 54 feet; at Sittingbourne 35, and at the eastern edge of the district 10 feet higher. About a third of the district is Chalk, a third London Clay and Lower London Tertiaries, with gravels and brick-earth, and the remaining third (roughly speaking), on which there is very little population, is alluvium.

Sittingbourne and the adjacent *Milton* with other villages are placed at the junction of the Tertiaries with the chalk on a moderate slope, and with more or less brick-earth. Parts of Milton are on alluvium. *Rainham* is on chalk with patches of Thanet Sand and, perhaps, some brick-earth. Bordon and many other villages are placed on the chalk, or on Tertiary outliers over it. The lower beds of the Thanet Sand which form these outliers are less pervious than the bulk of that formation. Newington and Hartlip are on Tertiary Sands; the former in a valley, yet at a fairly high level, and with good slope. Except *Little Halstow* and a few small places, which are situated on patches of gravel or sand, there is no population on the marsh area of the district.

Approximate number of residents upon alluvium, 500; gravel on London Clay, 270; uncovered London Clay, 760; Lower London Tertiaries, 7,480; chalk, 5,765.

Phthisis death-rate for males	- -	222
" " females	- -	330.

Ague is rather common in this district, especially about the Swale. There is some at Sittingbourne.

[6.] GODSTONE, Surrey. Acres, 43,848. Population, 9,642.
Maps 6 and 8.

Godstone.

The northern part of the district is Chalk; then follows a central band of Upper Greensand, Gault, and Lower Greensand, and to the south is a broad tract of Weald Clay, with a very small bit of Hastings Beds. Except the Weald portion, the district is undulating and fairly high.

Godstone, Bletchingley, Lympsfield, and *Oxted* are the largest places, but none of them are more than villages. They are all on the Lower Greensand, and a sandy part of it; the two former having a band of more loamy sand cropping out below the town. The slope of the ground and the dip of the beds, however, is such as to allow of water getting readily out of the soil beneath these places. All these villages are on good slopes at fair altitudes.

Caterham, Warlingham, Chelsham and some smaller places are on chalk; they mostly lie high where the chalk is capped by gravels and brick-earth, but some parts are in valleys of the chalk; only farms and scattered hamlets occur on the Weald Clay.

Approximate number of residents on Chalk, 2,242; on Upper Greensand, 60; on Gault, 50; on Lower Greensand, 5,670; on Weald Clay with some gravel, 500; on the same without any gravel, 1,050; and on Hastings Beds, 70.

Phthisis death-rate for males	- - -	241
" " females	- - -	323.

Note the small population, causing rates to be affected by numerically few cases of phthisis.

[7.] NORTH AYLESFORD, Kent. Acres, 41,732. Population, 19,121.
Maps 1 and 6.

North Aylesford.

A Chalk district in the main, the Chalk forming a slight trough from east to west across its area, with the highest ground at the south. Beds of the Lower London Tertiaries, chiefly pervious, cross the

district in the same direction, and there is a small uninhabited piece of London Clay.

Northfleet and *Strood* are the largest places. The former lies 80 or 100 feet above the Thames, on Chalk covered by brick-earth and gravel; adjacent parts are on Thanet Sands. *Strood* with *Frindsbury* are on the same formations, great part lying low near the level of the Medway, but other parts of them being on rapidly rising ground. Some houses of Strood are on alluvium; parts of Frindsbury on Thanet; Meopham with smaller villages stands on Chalk. *Shorne* and *Cobham* are on sandy tertiaries over Chalk, on a good slope. *Lower Halling* is at a lower level near a marsh, on gravel over Chalk. *Cliffe* is on bare Chalk, sharply scarped towards the river.

Approximate number of residents on alluvium, 276; on Lower London Tertiaries, 3,500; on Chalk, 15,345.

Phthisis death-rate for males	-	273
" " females	-	306.

[9.] DOVER, Kent. Acres, 29,881. Population, 31,575. Map 3.

Dover.

A high Chalk district cut through by the valley of the Dour.

Dover itself is largely built upon shingle and estuary alluvium, the higher parts upon a coarse rubble of fragments of chalk and flints. The Castle, the Citadel Barracks, and some houses of the town are upon bare chalk. *Charlton*, *Buckland*, and *River* are in the valley, on sharp slopes, on chalk or similar rubble to that of Dover. Charlton is slightly on alluvium. Other villages are on dry Chalk, generally lying high.

Estimated number of residents on alluvium, 1,791; on shingle, 8,000; on Chalk, 21,534; on vessels, 250.

Phthisis death-rate (registered) for males	-	303
" " females	-	289.

The occupation of many males being very special, and the true mean number of males being uncertain, the published male rate appears to be of inferior value. But as corrections made on these two grounds would probably be in different directions, with a tendency to put the male rate higher, it is thought better to adhere to the mean of registered rates in assigning Dover its place in the series of districts, rather than to deduce a new mean from the lower female rate.

[10.] BROMLEY, Kent. Acres, 39,927. Population, 20,368. Maps 1 and 6.

Bromley.

The southern part is of chalk with local cappings of surface clay; the ground slopes downwards from south to north, following the dip. The northern portion is a Tertiary country, rising from the chalk by a sharp escarpment about the middle of the district, and sloping downwards to the north. This consists of outliers of London Clay, on a broad tract of pebble beds underlain by sands and clays. The eastern part of the district is intersected by the valley of the Cray.

The largest places are *Bromley*, *Beckenham*, and *Chislehurst*, mainly on pebble beds and sands. Very small portions of these places are on the more retentive Woolwich Beds and London Clay. Some smaller places are similarly situated. From their elevation and the slope of their beds they must be dry. Along the Cray Valley are the four villages of the *Crays* and *Orpington*, seated indifferently on alluvium, gravel, Thanet Sand, and Chalk. Almost all the houses are on pervious

strata, bordering streams on slightly sloping ground, but lying rather low. *Farnborough* and *Keston* are high up on the slope of the Tertiary escarpment. *Cudham, Chesterfield, Knockholt, Down,* and other places are on Chalk.

The road from Bromley through the centre of the district towards Sevenoaks gives a fair notion of the slopes of the district. These are numerous and varied, the extremes of height being 350 and 210.

Estimated number of population living on alluvium, 368; on uncovered London Clay, 1,000; on Lower London Tertiaries, 15,500; and on Chalk, 3,500.

Phthisis death-rate for males	- - -	285
„ „ females	- -	303.

These death-rates are somewhat lower than they should be, through the method adopted in the published return of taking the arithmetical mean of two censuses, instead of the true mean number of a rapidly increasing population.

[11.] STEYNING, Sussex. Acres, 44,344. Population, 24,053.
Map 9.

Steyning.

Geologically is in two parts; a northern smaller part of Weald Clay, Lower Greensand, Gault, and Upper Greensand, and a southern larger part of Chalk. Both parts are intersected by the valley of the Adur. The Weald Clay and the Gault are wet and low, the other formations mainly high and dry.

Hove, a suburb of Brighton, is the largest place, situated on a flat of chalk, partly covered by gravel or chalky rubble, with a little brick-earth. The elevation of the church is 44 feet above the mid-level of the sea, and there is no water within 20–30 feet of the surface. *Shoreham* is next in size. It lies low, and, with *New Shoreham, Southwick,* and other villages, on chalk, bordering the sea or near a river, and capped by alluvium or a few feet of brick-earth on the chalk. *New Shoreham* lies flat, at about high-water mark. *Steyning* is at the foot of the Chalk hills, near the junction of the Chalk and Lower Greensand. Its soil is dry, water not coming nearer to the surface than 19–20 feet. *Henfield* and smaller villages are on Lower Greensand. Henfield is partly on the clayey (Sandgate) beds. A few small places lie on the Weald Clay, at its junction with the Lower Greensand. The ground is everywhere undulating, and the Chalk rises to hills of considerable height.

Estimated number of residents on alluvium, 120; on Chalk, 18,993; on Upper Greensand, 1,560; on gault, 53; on Lower Greensand, 1,920; on Weald Clay (without gravel), 1,030; and 377 persons were on board vessels.

Phthisis death-rate for males	- - -	287
„ „ females	- -	304.

[12.] CHERTSEY, Surrey. Acres, 43,541. Population, 18,642.
Map 8, and Section No. 74.

Chertsey.

In the main this district consists of Bagshot Beds, with gravel and alluvium at the lower levels; the middle and lower members of the Bagshot series are most represented, the middle being more or less clayey, the lower nearly pure sand.

Chertsey (with *Addlestone*) and *Walton* (with *Hersham*) are the largest places. These, with *Weybridge* and *Byfleet*, are on thick beds of gravel, for the most part underlain by Bagshot Sands, but at Walton

and Hersham by London Clay. Except Chertsey and Byfleet these villages are on fair elevations, but the latter places lie low near streams, and near Chertsey the land is liable to be flooded. *Chobham* is a largish village on gravel, lying low, near a stream. *Bagshot* and *Windlesham* lie on a slope of the middle Bagshot Beds.

Approximate number of residents on alluvium, 400; on gravel over London Clay, 5,400; on Bagshot Beds, 12,842; of which 2,400 may be taken as on the less pervious Bracklesham Beds.

Phthisis death-rate for males	- -	268
" " females	- -	325.

[13.] CROYDON, Surrey. Acres, 32,803. Population, 46,474. Maps 6 and 8.

Croydon.

Of this district the town of Croydon forms so large a proportion that its rate must largely govern that of the whole. It stands at the junction of the Chalk and Tertiaries, where that line is cut through by the valley of the Wandle. Over the Thanet Sands, Woolwich Beds, and London Clay there is a thickish covering of gravel (15 feet or so) in many parts of the town. The Wandle is here a nailbourne, and rises at various points along the valley according to the wetness of the year. The works that have been undertaken for the sanitary improvement of Croydon were in the main completed in 1853, or at the early part of the period to which the subjoined phthisis rates refer. Before their execution the lower parts of the town were very wet, as might be inferred from geological considerations, and the roads were charged with water in wet weather. The drainage works of 1850–53 consisted, *inter alia*, in the removal of a milldam, the construction of a culvert to take off the water of the chalk in wet seasons, and the pumping of much water from deep wells. A notable influence was produced on the water of the soil, and it is shown in the Report of last year (page 102) that, simultaneously with this change, a considerable reduction of the amount of consumption was effected.

Mitcham is on gravel over London Clay, on a slight slope bordering the Wandle. *Penge* and *Upper Norwood* are on London Clay, without gravel; the former stands somewhat low but on sloping ground, the latter at a high level. There are scattered villages situated either on the pebble beds and sands of the Tertiaries or on the Chalk, in either case having good natural drainage.

Approximate number of residents on alluvium, 474; on gravel over London Clay, 16,000; on London Clay without gravel, 11,600; on Lower London Tertiaries, 9,800; and on Chalk, 8,600.

Phthisis death-rate for males	- -	331
" " females	- -	275.

Besides the consideration above stated, observe that Croydon town and some other parts of the district are much used as a residence by well-to-do Londoners; and consider further, that in the case of a rapidly increasing population, the method by which the published rates are computed, viz., on the arithmetical mean population between two censuses—by making the population larger than the true mean of 10 years—makes the published rates unduly small.

[15.] CRANBROOK, Kent. Acres, 40,249. Population, 13,412. Maps 5 and 6.

Cranbrook.

A district of the Hastings Beds, consisting of hills and valleys of Tunbridge Wells Sands and Wadhurst Clay, with a small patch of

Weald Clay at the north-east. In several places, in valleys and along faults, Ashdown Sand comes to the surface. The area may be considered as two-thirds sand and one-third clay. It rises to a moderate elevation: from 200 to 400 feet above the sea level.

Cranbrook itself is on a rise of Tunbridge Wells Sand above Wadhurst Clay, with good natural drainage. *Goudhurst* is on much the same formations, but is placed on a sharper slope and on higher ground. *Hawkhurst* and various villages on the south of the district lie just on the junction of the same sand and clay, evidently having been placed here for facility of obtaining water. *Benenden* is on the Wadhurst Clay; *Frittenden* on Weald Clay.

Of the residents in this district 100 are estimated to live on Weald Clay with gravel, 800 on Weald Clay without gravel, 1,200 on the clays of the Hastings series, and 11,312 on its sandy beds.

Phthisis death-rate for males	-	242
" " females	-	381.

[16.] RICHMOND, Surrey. Acres, 4,339. Population 18,802. Map 7.

Richmond.

This district is bounded on the north and west by the Thames, and consists wholly of London Clay, in great part covered by gravel and sand, but with very little alluvium. The gravel makes a broad flat along the Thames, except at the southern part of Richmond, where the London Clay is touched by the river, and forms a steeper bank for half a mile. There are also flat caps of gravel on the clay hills of Richmond Park. The London Clay rises up from beneath the gravel southwards and eastwards.

Richmond is placed at the edge of the low-level gravel, and partly on the rising ground of London Clay on the south. *Petersham, Kew, Mortlake,* and *Barnes* are on the gravel.

Twelve hundred people are estimated to live on London Clay without gravel, and the remaining 17,602 of this district upon gravel over London Clay.

Phthisis death-rate for males	-	375
" " females	-	251.

[17.] KINGSTON, Surrey. Acres, 22,487. Population, 36,479. Maps 7 and 8.

Kingston.

A district almost wholly of London Clay covered by gravel, along the Thames. Esher alone is on a patch of Bagshot Sand.

The greater part of *Kingston* is on gravel over London Clay, the surface of the ground sloping slightly (but that of the clay rather more) towards the river. Some newer parts of the town are on a slope of the clay. Probably the waterline in the gravel is about 10–15 feet from the surface. *Thames Ditton* and *East and West Molesey* are similarly placed on gravels over clay, but without the rising ground of clay behind. *Wimbledon, Long Ditton,* and *Malden* are almost wholly on gravels over London Clay.

Approximate number of residents on Bagshot Beds (all pervious), 1,460; on London Clay with gravels, 28,839; on the same without gravels, 6,200.

Phthisis death-rate for males	-	352
" " females	-	279.

Kingston may be taken as an illustration of the error arising from the method in which the death-rates of Parliamentary return No. 12 have been computed. The rates have been taken on the arithmetical mean of the population at the two censuses, 1851 and 1861. This is larger than the true mean number of people living in the district between the two censuses. The death-rates consequently come out smaller than the true death-rates. In Kingston district the death-rate of females, 15–55, from phthisis is given (Parliamentary return) at the above figures, 279. Computed upon the more correct mean number of females at that age, with the assumption that the rate of increase was uniform between 1851 and 1861, the death-rate in females was 287; or computed on the data of the three censuses 1841–51–61, which show that the rate of increase was itself rapidly increasing, the truest death-rate that can be got for females aged 15–55 turns out to be 293.

Now Kingston, especially in its female rate of increase, is an extreme example among the districts under consideration, of a district altering its population otherwise than by the natural methods of increase. This being so, and the extent of error being at the most only between 279 and 293, the death-rates given for other districts in the Parliamentary return may be taken as seldom varying very seriously, by reason of population fallacies, from the true rates.

[18.] ELHAM, Kent. Acres, 43,197. Population, 26,925.
Maps 3 and 4.

Elham.

The northern two-thirds are mostly high, and consist of Chalk with irregular patches of surface clay and a little sand, but this part is thinly populated. The southern third is at a considerable height, and consists of Gault with Lower Greensand (the Upper Greensand being here insignificant), with Weald Clay at the extreme south, at Hythe; hereabouts, too, a small part of the district is on marsh.

Folkestone is the chief town. The eastern and north-eastern parts of it (which only lately have been much built on) are on gault, on a gentle slope. The main part is on the upper division of the Lower Greensand, which here consists of sand with irregular layers of sandstone, the "Folkestone Beds." The levels of the town range from 66–118 above mid-level of the sea. East Cliff and West Cliff have both good slopes to the valley, and the soil must everywhere be very dry, except perhaps in a few small places where brick-earth and gravel occupy the valley.

Hythe is at the foot of the escarpment of Lower Greensand, where the Atherfield and Weald Clays are covered by masses of the pervious strata fallen from above. Its southern part is on shingle. The ground on which the town stands slopes downwards pretty rapidly from north to south. Above the town, on the north, the pervious Lower Greensand stands in cliffs. On the east and west of the town, however, there are deep valleys in which the waters of the Greensand are thrown out by the Atherfield Clay, and this bed lies not far below the surface, in the principal part of Hythe. There are many springs at and just above the town. *Sandgate* is mostly on the loamy beds of the middle division of the Lower Greensand facing the sea, some 10 feet above high-water mark. *Elham* and *Lyminge* are on a strip of gravel in a chalk valley, the latter place at a watershed; and they are dry enough. Other villages on the chalk are on spots where thin caps of clay or gravel exist, at high levels and dry. The camp at Shorncliffe, with 4,204 military in 1861 (none in 1851), is on the Folkestone Beds before mentioned, on a well-drained soil.

Of the population of Elham district, it is estimated that 370 live on alluvium, 3,975 on Chalk, 2,660 on Gault, 17,420 on Lower Greensand, and 2,500 upon Weald Clay.

Phthisis death-rate for males - - -	232
„ „ females - -	323.

Note the soldiers as a probable disturbing element of the male rate.

[19.] BLEAN, Kent. Acres, 32,221. Population, 16,161. Map 3.

Blean.

A Tertiary district. The divisions of the Lower London series crop out along a line roughly parallel to the channels of the Stour and Wantsome on the south and east. To the north and west of this line London Clay forms a hilly wooded country, with drift gravel on its higher parts. Along the Stour there is in many places a slope of gravel and brick-earth, and a flat of alluvium.

A north-west *suburb of Canterbury* reaches into this district. It is on a slope (120 to 60 feet) of brick-earth over Thanet Beds and chalk. *Whitstable* is on shingle and alluvium, lying low, nearly on the sea level. The town of *Herne Bay* is on almost a flat of London Clay, 20–30 feet above the sea. *Herne* itself is on an inlying patch of the sands below this clay. *Sturry* lies on a flat of gravel just above the Stour (15–16 feet above mid-level of the sea), where the river ceases to be tidal; it must be water-logged. *Blean* village stands on a slope of London Clay, where it is thinly capped by gravel. Other places are on the Lower London Tertiaries or at the edge of the London Clay, and do not appear to be wet.

Approximate number of people living on alluvium, 2,100; on shingle, 700; on London Clay, gravelled, 950; without gravel, 5,800; on Lower London Tertiaries, 6,611.

Phthisis death-rate for males - - -	286
„ „ females - - -	344.

A small addition to these rates should be made for patients of Blean dying in the Kent and Canterbury Hospital, but the amount of this correction is inconsiderable.

[20.] BRIDGE, Kent. Acres, 41,394. Population, 11,316. Map 3.

Bridge.

Consists of a northern part of sandy Tertiaries and a southern part of Chalk, the former lying somewhat low and sloping towards marsh, at the edge of the Stour, the latter consisting of high downs with valleys, in some of which intermittent streams (known as nailbournes) occur.

Along the valley of the Little Stour, which is often dry in a great part of its course, there are eight or ten villages on Chalk or valley gravel, evidently placed here for the sake of water. Other villages are on the high Chalk country. *Chartham* and some other places on the Great Stour are very probably kept wet by the milldams in the river at Canterbury. *Fordwich* and *Stodmarsh* are near the same river, where it is tidal below Canterbury, on low lying tertiary sands and valley gravel.

Number of residents estimated to live on alluvium, 400; on uncovered London Clay, 50; on Lower London Tertiaries, 3,680; and on Chalk, 7,186.

Phthisis death-rate for males - - -	244
„ „ females - - -	418.

In 1851–60, seven males and two females from Bridge died in the Canterbury Hospital of phthisis, being between the ages of 15 and 55.

This was the largest number of deaths from any outlying district occurring there, and correction has therefore been made for them. This is a good illustration of the degree of disturbing influence likely to arise from the presence of a county hospital in an adjoining district. The corrected rates are—males, 259; females, 425; and the difference from the registered rate is therefore of no material amount.

Gravesend.

[21.] GRAVESEND, Kent. Acres, 1,541. Population, 18,782. Map 1.

A small district, comprising *Gravesend* and *Milton-next-Gravesend*, which form a single town only. It consists of a Tertiary outlier of the Thanet, Woolwich, and Oldhaven Beds, upon Chalk. Upon the slope of this outlier, and on Chalk between it and the Thames, the town of Gravesend is built, the greater part being on Chalk and Thanet Sand. The only impervious portions in this outlier are clays in the Woolwich Beds and clayey parts at the bottom of the Thanet Sand. In view of these, and of the slightly troughed nature of the base of such outliers as these, there is a likelihood of small portions of the town being here and there damp. Near the edge of the river, too, the foundations of the houses are near the water-line of the chalk; but the great bulk of the people live on quite porous and sufficiently sloping dry soil.

Estimated number of people resident on alluvium, 50; on Lower London Tertiaries, 4,000; and 13,989 on Chalk; and 743 on board vessels.

Phthisis death-rate for males - - -	479
„ „ females - - -	331.

Observe the very disproportionate male death-rate, of which the only explanation that can be suggested is, that Gravesend is not a little used by the poor of the east end of London, who, when they get consumptive, find this town cheap, and to their notions like the sea-side. This use of the town would probably be more by males than females.—Ague is on the decrease in Gravesend, except in so far as it is imported from Essex. On the dispensary books 61 cases of intermittents appeared in 1856, 371 in 1859, and 235 in 1860.

[22.] EAST GRINSTEAD, Sussex and Surrey (*Lingfield*). Acres, 61,317. Population, 14,097. Maps 5, 6, 8, 9.

East Grinstead.

A wholly rural district, on the various sands and clays that make up the Hastings Beds of the Wealden series. Very small part of Weald Clay; more than three-quarters of the area are sand. There must be considerable variety of natural drainage here, but for the most part it is good, the beds as well as the contour of the country having a fair slope. Crowborough Beacon, the highest point in the Wealden country (800 feet), is at the south-east edge of this district, on the boundary of Uckfield.

The largest place is *East Grinstead* itself; a long street in the course of which are found alternations of sands and clays, known as the Upper Tunbridge Wells Sand, the Grinstead Clay, the Lower Tunbridge Wells Sand, and the Wadhurst Clay. Most of the town is on a slight rise of the Lower Tunbridge Wells Sand, the clay beneath sloping away so that the sands cannot be water-logged. *Hartfield*, *Withyham*, and *Forest Row* are on the Ashdown Sand, near the bottom of a valley, where the ground slopes towards a stream. *Crawley*, at the north-western corner of the district, is on Weald Clay, flat and moist. Part of *Lingfield* is on Weald Clay, part on Hastings Beds.

Approximate number of population living on Weald Clay (without gravel), 1,650 ; on the sands of the Hastings Beds, 11,547 ; on the clays of the same, 900.

Phthisis death-rate for males	- - -	303
„ „ females	- - -	363.

[24.] REIGATE, Surrey. Acres, 51,276. Population, 20,109. Map 8.

Reigate.

The northern quarter of this district is Chalk with local cappings of surface clay and loam, and some outliers of Thanet Sand. Then across the district, from east to west, run narrow bands of Upper Greensand and Gault, with a broader band of Lower Greensand. The southern two-thirds of the district is Weald Clay, in great part capped with gravel, particularly along the streams. This clay is not altogether flat ; the London and Brighton railway passes through some six miles of it, in which are elevations of 210, 250, 180, 210, 150, and 185 feet—a good deal of variety for a Weald Clay district.

Reigate and *Redhill* are placed on the edge of the Gault and on Lower Greensand ; they are mainly on the upper more sandy division of the Greensand, the middle more clayey division cropping out south of the town. Their natural drainage must be good and their soil dry. Besides other places on the Lower Greensand, *Betchworth* is on the lowest sandy and stony beds of this formation, where it is capped by some gravel ; the western part of Betchworth, however, lies low and flat, nearly upon Weald Clay.

Headley and *Walton-on-the-Hill* are on sand outliers over chalk. Upon the remainder of the chalk area are scattered villages and hamlets. *Gatton* and *Merstham* are on Upper Greensand ; a part of the latter stretches down to the Gault, but on Gault itself there is scarcely any population. On the Weald district are many small villages and farms, most of them being placed on the thin irregular beds of gravel which overlie the clay.

Estimated number of residents on London Clay (uncovered), 50 ; on Lower London Tertiaries, 350 ; on Chalk, 1,480 ; on Upper Greensand, 1,020 ; on Gault, 240 ; on Lower Greensand, 10,580 (of whom 1,000 may be taken to be on the Sandgate Beds) ; on Weald Clay with gravel, 4,389 ; on the same without gravel, 2,000.

Phthisis death-rate for males	- - -	322
„ „ females	- - -	352.

[25.] EASTBOURNE, Sussex. Acres, 38,072. Population, 10,721. Map 5.

Eastbourne.

A coast district. The southern half is bare chalk and high ground. The north-eastern half slopes from the Chalk downwards, over Upper Greensand, Gault, Lower Greensand, Weald Clay, and Tunbridge Wells Sand, to the Pevensey Level, marsh and Weald Clay.

Eastbourne village is at an elevation ranging from 89 to 21 feet, on the edge of the Chalk, and the new town stretches over the Upper Greensand. Below this is the impervious Gault clay, the slope of which however is such as not to affect the natural drainage of the houses that lie on the pervious beds above. *Seaford* is on Tertiary Sand over Chalk, on a river at the edge of the sea, and must also have good natural drainage. *Pevensey* and *Westham* are low-lying places (21 to 10 feet), at the edge of the marsh land. Several small villages lie either at the junction of the Chalk and Upper Greensand, or else on the chalk, at various levels. *East Dean* has 144 feet of altitude. *West Dean,*

Lullington, and *Alfriston*, being in valleys, may have the subsoil water near the surface.

Approximate number of residents on alluvium, 60; on shingle, 200; on Lower London Tertiaries, 1,000; on Chalk, 5,071; on Upper Greensand, 3,160; on Lower Greensand, 50; on Weald Clay without gravel, 100; and on sand of the Hastings Beds, 1,080.

Phthisis death-rate for males	- - -	280
" " females	- - -	392.

Possibly these rates might be a trifle lower if deduction were made for visitor invalids dying at Eastbourne.

[26.] FARNHAM, Surrey. Maps 8 and 9. Acres, 31,197. Population, 30,707; having increased from 11,743 in 1851, mainly by reason of the establishment of Aldershot Camp.

Farnham.

It is a long straggling district. Tertiary and secondary formations are represented in it from the Bagshot Beds at the north, to the Lower Greensand at the south. The Bagshot Beds form high ground, the less pervious members of the series (Bracklesham) being on the slope of the hill, which has sands (Upper Bagshot) and more or less drift gravel at the top. The London Clay then (with various undulations) slopes downwards to the valley of the Blackwater, where clayey Reading Beds form a narrow flat tract, which is however uninhabited. Then the chalk rises in a gentle hill, on the other side of which the lower ground —the valley of the Wey and a branch of it—is formed by Gault, cropping out with considerable dip. From hence the Lower Greensand rises to a considerable elevation.

Aldershot South Camp, and the towns that are creations thereof, are on a fair elevation and slope, on the upper and middle divisions of the Bagshot Beds, bordering the Blackwater. Parts of the village of Aldershot extend on to London Clay. *Frimley* stands on gravel, and a small part on alluvium. The town of *Farnham* is chiefly on gravel over Gault, small parts being on alluvium, on Chalk, and on gravel over Lower Greensand. *Wrecklesham* is somewhat similiarly circumstanced. Artificial drainage would certainly be required to keep such a soil as this from being wet over a great portion, and this has not been supplied upon any considerable scale. There are outlying villages on the Lower Greensand; the chief of them, *Frensham*, is in the valley.

Approximate number of residents on alluvium, 300; on Bagshot Beds, 20,457 [an unknown portion of whom (in Aldershot Camp) are on the Bracklesham division]; on uncovered London Clay, 3,220; on Chalk, 200; on Upper Greensand, 50, Gault, 2,680, and Lower Greensand, 3,800; all of which last may be taken as sandy.

Phthisis death-rate for males	- - -	236
" " females	- - -	349.

Note that the military hospital for the whole of Aldershot Camp (including the northern part in Farnborough district) is situated here. The male rate cannot be corrected, and as it stands is of no value. The female rate is probably subject to certain minor disturbing influences, but their effect cannot be estimated.

[28.] HAMBLEDON, Surrey. Acres, 60,351. Population, 13,907. Maps 8 and 9.

Hambledon.

The northern and western boundaries of the district project into a Lower Greensand country, where sand and calcareous sandstone form high ground that slopes to the north, and has excellent drainage. This

part, though of small area, has nearly half the population. The remainder is a tract of Weald Clay, with a patch of valley gravel; the population here is in scattered hamlets. The Section of the Geological Survey, No. 73, running northward from Haslemere across the Hog's Back into part of the Farnborough district, shows well the shape of the ground and the arrangement of the beds in the western part of this district.

Haslemere is on Lower Greensand, at the junction of the Hythe Beds, (sandy and stony), with Atherfield Clay. The houses are built on the pervious strata beds, of which there is here but a small thickness above the clay. *Witley*, *Thursley*, and other places, are also on the Hythe Beds, at good elevation, the clay having a good slope beneath the pervious beds. *Bramley*, *Wonersh*, and *Elstead* are similarly placed, on gravel at the edge of streams. On the Weald Clay, *Crawley* and *Chiddingfold* are the chief places; the former lies low, and is necessarily wet; the latter is on some slope towards a stream.

Estimated number of population living on Lower Greensand, 6,837, all of them on sandy beds; on Weald Clay, with more or less gravel, 2,820; on Weald Clay without gravel, 4,250.

Phthisis death-rate for males	- - -	275
" " females	- - -	411.

[29.] BATTLE, Sussex. Acres, 54,000. Population, 12,680. Map. 5.

Battle.

The whole district is on the Hastings Beds of the Wealden series; nearly half is Wadhurst Clay; there is a little alluvium, and the rest (more than half) is sand. The general contour is a ridge running from N.W. to S.E. through the centre of the district, with irregular subordinate ridges with streams in the valleys between them. The elevation of the ground is moderately high, its highest part being 600 feet.

Battle is on a moderate hill, at the edge of a bed of clay. The ground sloping from the town on the N.E. is sand, on the S.W. clay. There is good surface drainage, and the underground drainage is probably a good deal facilitated by the adjacent ground being faulted. *Bexhill*, the next largest place, lies with neighbouring parts, on a hill of sand over clay (100–150 feet elevation), and the surface slopes down from it in all directions. *Seddlescombe* is on sand, sloping to a brook. The villages generally stand on high ground, and not immediately upon streams. In this position they have excellent facilities for natural drainage.

Estimated population living on clays of the Hastings Beds, 2,500; the remaining 10,180 being on the sands of that formation.

Phthisis death-rate for males	- - -	250
" " females	- - -	338.

[30.] CANTERBURY, Kent. Acres, 3,121. Population, 16,643. Map 3.

Canterbury.

The registration district includes only part of the city, which extends into Bridge and Blean districts. The district lies on the right bank of the Stour, and part of it on an island formed by the division of the river. The streams here are greatly dammed up, and the houses are built quite to the edges of them. The range of elevation in the city is from 35 to 25 feet above the mean level of the sea. The island and some parts beyond the eastern division of the river are on alluvium, and are subject to be flooded. From this flat tract rises a gentle slope of gravel and made earth, and on these the cathedral and the greater part of the town

stand. At the south-east chalk comes to the surface, and at the north-east Thanet Beds capped by gravel. On these formations houses are built in the outskirts of the town. Any artificial drainage that has been done in the city, and it is too recent to affect the rates on which this inquiry proceeds, can have had little effect on subsoil, as the milldams are preserved, and the town is still liable to floods at its lowest levels. Wells in the town are supplied from the superficial porous strata, largely assisted by percolation from the river. Water is reached at 6–10 feet below the surface. The barracks get a copious water supply from the chalk.

Approximate number of residents on alluvium, 1,600; on Lower London Tertiaries, 3,000; and on Chalk, 12,043.

Phthisis death-rate for males	- - -	441
„ „ females	- - -	328.

Note the presence of the Kent and Canterbury Hospital as a slight cause of artificial increase in these rates. Note also the barracks (1,597 soldiers) and the county prison (93 inmates). Mr. Reid, of Canterbury, has enabled correction to be made for the deaths of persons dying in these establishments, and not having previously resided in the district. Thus corrected, the male rate becomes 400, and the female 298.

[32.] HOLLINGBOURNE, Kent. Acres, 57,017. Population, 13,584. Maps 3 and 6.

Hollingbourne.

Consists (*a*) in its northern half of a Chalk country, about 600 feet high at the escarpment, and falling thence northward with a gradual slope; and (*b*) in the southern half of a narrow strip of Gault with a broad band of Lower Greensand (sand and limestone), forming a rising ground near the Chalk escarpment; and (*c*) a flat of Weald Clay, wet and low, with patches of gravel over it.

Lenham, Boxley, Hollingbourne, with smaller villages, lie at or near the bottom of the Chalk escarpment, partly on the Chalk, partly on the gault. *Stockbury* and other places are on Chalk. The two *Suttons, Leeds,* &c., are on the lowest beds (Kentish Rag over Atherfield Clay) of the Lower Greensand, high, on a good slope. *Headcorn* is a village on the Weald, bordering a brook, and lies low, with a slope of only some 15 feet in a mile.

The population living on chalk is about 4,330; on gault, 1,250; on Lower Greensand, 5,074; on Weald Clay, 2,930, of whom 500 are on more or less of gravel.

Phthisis death-rate for males	- - -	310
„ „ females	- - -	394.

[33.] MALLING, Kent. Acres, 47,398. Population, 21,447. Map 6.

Malling.

On the north this district has a narrow portion of the chalk escarpment; then a belt of Gault lying at a much lower level and wet: then follows a broad tract of Lower Greensand (sand and Kentish Rag), gradually rising upwards to the south to a height of 400 feet, and having on it the greater part of the population. On the extreme south there is Weald Clay, slightly covered with gravel, mostly over 100 feet above datum, and in some parts as much as 200 feet.

Wrotham is the largest place; it stands high, on chalk, at the foot of a hill near gault. *Snodland* is low, on gault, where some gravel covers it, at the edge of the Medway. *Burham* and *Trotterscliffe* are also on gault.

West Malling and many other villages are scattered over the Lower Greensand country, from the Gault to the Weald Clay; all are on fair slopes. The two *Peckhams*, *Wateringbury*, and *Mereworth* are at or near the junction of the Kentish Rag with Weald Clay; but their elevation appears such as to allow of natural drainage. *Aylesford* is lower, on gravel over sand (Folkestone Beds), bordering the Medway.

Small villages only, of no consequence, are on the Weald Clay, mostly where there is some gravel over it.

Of the whole population, the approximate number on alluvium is 100; on chalk, 2,780; on gault, 1,630; on Lower Greensand (its pervious beds only), 13,300; on Weald Clay with gravel, 2,220, without gravel, 1,417.

Phthisis death-rate for males	-	-	-	290
„ „ females	-	-	-	423.

[34.] EAST ASHFORD, Kent. Acres, 54,498. Population, 12,286. Maps 3 and 4.

East Ashford.

At the extreme north a few houses stand on some high-lying Tertiary Sands. The northern third of the district is Chalk (with irregular cappings of clay and loam), at its usual high level. Across the middle, from east to west, runs a band of Gault clay covered, between Wye and Ashford, by a thin layer of loam or gravel, whilst on the east of the Stour it is lower and more wet. Then to the south, about half the district is Lower Greensand (sand, sandy clay, and limestone), and at the edge of Romney Marsh it comprises a little Weald Clay.

There is no place of 2,000 inhabitants in the district. *Wye* and *Kennington* are on slight slopes of gault at the junction with the chalk, parts of their sites being capped by gravel. The river Stour runs by Wye, and provides the gravel waters with ready exit. *Brabourne* and *Brook* are on slopes of gault without gravel. Other villages along the valley of the Stour are on chalk or on gravel, or caps of clay over it.

Willesborough, a largish village, and other smaller ones, are on more or less pervious beds of Lower Greensand, generally on a rise. At the extreme south are several villages upon Weald Clay bordering alluvium.

Approximate number of residents on alluvium, 200; on Lower London Tertiaries, 100; on Chalk, 3,650; on Gault, 2,480; on Lower Greensand, clayey parts, 600, sandy parts, 2,520; on Weald Clay without gravel, 2,486; on Hastings Beds, 250.

Phthisis death-rate for males	-	-	-	262
„ „ females	-	-	-	456.

Observe the striking difference in the rates of the two sexes.

[35.] SEVENOAKS, Kent. Acres, 67,488. Population, 22,039. Map 6.

Sevenoaks.

At the northern part of the district there is a little Chalk, at a high level, and partly covered with loam. Next a strip of Gault, about a mile broad (with an insignificant outcrop of Upper Greensand), crosses from west to east. Then comes a broad band of Lower Greensand, rising southwards to its escarpment (where the Kentish Rag is at a height of from 500 to 700 feet), succeeded by another broad band of Weald Clay. This is mostly flat, with very little gravel. The central parts lie at 100 to 200 feet above Ordnance datum, the southern part less, and the northern more (from 300 to 400 feet near the greensand escarpment). The southern quarter of the district includes various beds of the Hastings series, and of this about half consists of Wadhurst Clay, or is covered by alluvium.

Sevenoaks stands at a fair height, on the upper division (Folkestone Beds) of the Lower Greensand, on a pervious soil underlaid by the also pervious Kentish Rag. *Westerham*, on similar formations, is in a valley. These are the two largest places. *Sundridge*, *Brasted*, and other villages lie much like Westerham, and have besides more or less gravel along the stream in the valley. Water is probably near to the surface here. *Seal* is situated at a greater height on the same beds. *Edenbridge* is on Weald Clay on a river where there is valley gravel, but this place too is low. *Leigh* is a village on a slope of Weald Clay. *Penshurst*, on the country of the Hastings Beds, is on gravel over sand between two streams, where the ground is low and wet.

A section, No. 77, very recently published by the Geological Survey, shows instructively the contour of the country hereabouts, and the geological relations of the surface. It runs from Groombridge, on the boundary of Kent and Sussex, northward, along the west edge of the district, to Eynesford in the Dartford district. The county boundary is a brook, the watercourse being formed by drainage from a slope of Wadhurst Clay meeting the softer Tunbridge Wells Sand at a fault. For two and a half miles northward of this boundary the Wadhurst Clay, slightly troughed, is covered by Tunbridge Wells Sand and an outlier of Weald Clay, rising to a hill of some 400 feet. The valley of the Medway (100 feet above datum) is here formed by Ashdown Sand, flanked by Wadhurst Clay on either side. The Ashdown Beds, with Wadhurst Clay over them, rise on the west of the Medway to Rogues Hill, 250 feet high. To the north of the river the section runs through about four miles of Weald Clay, in which extent the differences of elevation do not amount to more than 30 or 40 feet. The South-eastern Railway is crossed by this section at a point about 160 feet above datum. [In the west to east course of that railway through the Weald, about eight miles are in the Sevenoaks district, at a part where the Weald Clay is more than usually undulating. There are six cuttings and three or four embankments in this distance; the common extremes of height are 200 and 140 feet, but one spot is only 105 feet high, where there is a stream and gravel.] In all the Weald Clay tract, except at the edges of streams, there are only scattered farms and hamlets. The northern edge of Weald Clay rises considerably near the junction with the Lower Greensand, where the altitude of 500 feet is rapidly reached, to which the Lower Greensand in the course of another quarter mile adds 200 feet more. From this point northward the Lower Greensand slopes down gradually with the dip to its junction with gault. This, with a thin band of Upper Greensand, begin a slight rise, upon which follows the great Chalk escarpment at the extreme north of the district.

Approximate number of residents on alluvium, 100; Chalk, 1,830; Upper Greensand, 510; Gault, 925; Lower Greensand (all pervious beds), 10,200; Weald Clay with some gravel, 1,220; the same without gravel, 3,640; Hastings Beds, 3,614, viz. 1,000 on clays, and 2,614 on sands.

Phthisis death-rate for males	-	-	-	295
" " females	-	-	-	427.

[36.] GUILDFORD, Surrey. Acres, 65,592. Population, 29,330. Map 8.

Guildford.

The northern half of this district consists of low-lying Tertiary beds, Bagshot Sands, London Clay, and Reading Beds. This Tertiary part is moderately undulating; within 7–8 miles the road from Guildford to Ripley shows elevations of 160, 106, 140, 84, 85, and 140 at six points pretty nearly equidistant. Across the middle, from east to west, runs a ridge of Chalk with very narrow bands of Upper Greensand and Gault parallel to it. The southern third of the district is a tract of Lower Greensand (with an inlier of Atherfield Clay and Weald Clay on the south of Guildford, covered by sand and gravel), and this part is well placed for height and natural drainage.

The town of *Guildford* is in the main on chalk, where the ridge is cut through by the valley of the Wey. Its elevation ranges from 300 to 140 feet. A portion of Stoke parish, comprised in the town, is on Reading Beds, at a very small slope. With this exception the town is on a slope, and dry. *Godalming* is the second largest place; situated on gravel and Lower Greensand close to a river, and rising gently (about 40 feet in a half mile) from the river. A part on alluvium has scarcely any houses on it.

Woking and some other places are on low-lying gravel and Bagshot Sands, between streams. The edge of Woking is on alluvium. *Worplesden* and *Pirbright* are on the middle and more clayey division of the Bagshot Beds, and are at a low level. A number of villages, *Horsleys* (2), *Clandons* (2), and *Merrow*, are placed at the junction of the Tertiaries with the chalk, parts extending over to the London Clay. *Shere*, *Compton*, and other places are on the pervious beds of the Lower Greensand, slightly sloping upwards from streams.

Approximate number of persons living on alluvium, 370; on Bagshot Sand, 5,450 (of whom 1,200 may be taken as on the clayey Bracklesham division thereof); on London Clay covered by gravel, 2,200; on the same without gravel, 2,550; on Lower London Tertiaries, 1,350; on Chalk, 8,200; on Upper Greensand, 20; Gault, 40; and Lower Greensand, 8,760 (the Sandgate Beds thereof being unrepresented); on Weald Clay, 380, of whom 280 live on more or less gravel over the clay.

Phthisis death-rate for males - - -	359
„ „ females - - -	379.

[37.] FARNBOROUGH, Surrey and Hants. Acres, 39,571. Population, 14,318. Maps 8 and 9.

Farnborough.

This district is cut into three parts by the Farnham registration district, with which it agrees in its chief geological features.

There is no town of any magnitude here. *Farnborough*, with the *North Camp* of *Aldershot*, is on Bagshot Beds, part of the village itself being on alluvium, but the camp being on a fair elevation, and dry. Other villages are in a similar situation. *Headley* and *Bramshott*, two of the largest villages, are on Lower Greensand.

Estimated number of population living on alluvium, 200; on Bagshot Beds (of whom 500, besides some of the military, may be taken as living on the Bracklesham division) 8,620; on uncovered London Clay, 1,320; on Lower London Tertiaries, 500; on gault, 100; and on Lower Greensand (without clay), 4,128.

Phthisis rate for males - - - -	201
„ „ females - - - -	381.

Note special occupation of 3,029 of male population, any of whom when they are ill are sent out of the district to hospital. To obtain a truer mean rate for the sexes, the average difference between the mean rate and the female rate observed in the south-eastern counties generally (and amounting to 10 per 100,000 yearly) has been subtracted from the registered female rate, and the adopted mean rate of 371 has thus been obtained.

[38.] EASTRY, Kent. Acres, 50,710. Population, 25,900. Map 3.

Eastry.

The northern part of this district, about one-third of the whole area, is on Tertiaries, chiefly consisting of sand, with small slope and northward dip. The southern two-thirds are chalk, also sloping and dipping

northwards, with thin sandy or loamy soil in parts. On the north-east is a strip of marsh.

Deal—the whole sea face and the main part of the town are on shingle and seasand; some inland parts are on sandy brick-earth over Chalk, and Upper Deal is on Chalk itself. Most of the town is very low, and protected by the sea bank; its elevations range from 22 to 9 feet above mid-level of sea, and parts are therefore below high-water mark. The beds under the town are pervious but waterlogged, and the lower parts of houses get flooded in spring tides or storms. Some drainage recently done has probably improved the town in this respect. *Sandwich* is almost on an island of Thanet Beds (sand over sandy marl), and small parts are perhaps on shingle. The town is at a very small elevation (from 26 to 14 feet), with river on two sides, and marsh on the others. *Ash, Woodnesborough, Preston,* and other places are on Tertiary (Thanet and Woolwich) Sands, at more or less elevation, and necessarily dry soil. *Wingham* and *Staple,* being on the lower more marly parts of the Thanet Beds, and lying in a valley, may be more wet. *Walmer, Eastry,* and many other villages, furnishing about half the population of the district, are on chalk at various elevations; some with a loamy soil over the chalk. But everywhere here the chalk is dry, the valleys even having no streams.

Approximate number of residents on alluvium, 460; on shingle and sea-sand, 5,500; on Lower London Tertiaries, 6,850; on Chalk, 13,090.

Phthisis death-rate for males	- - -	357
„ „ females	- - -	385.

The marine hospital and barracks at Walmer are a possible disturbing element to this rate, but can operate only to an insignificant degree.

[39.] FAVERSHAM, Kent. Acres, 46,448. Population, 18,867. Map 3.

Faversham.

A district mainly of Chalk, sloping downwards with the dip from south to north, with valleys and ridges running in the same general direction. On the Chalk is an irregular thin capping of clay, and there is gravel in the valley bottoms. The eastern fifth of the district and a portion near the Thames estuary are Tertiary; the eastern part being high wooded hills with nearly level tops and a sharp slope downwards on the west, formed by gravel-covered London Clay at the top, and the Lower London Tertiary Sands cropping out at the foot. Near the river also are Tertiary Sands and clay with drift brick-earth and gravel and low flats of alluvium. This is the most populous part.

Faversham is situated at the junction of the Tertiaries and Chalk, on Thanet Sand and marl and brick-earth. It is at the head of a creek, with very slight slope to the river. Its levels range from 30 to 45 feet above mid-level of the sea, but it is generally flat. Parts of adjacent parishes are similarly placed.

Teynham is on brick-earth and Thanet Sand, at the edge of a marsh, in a wet situation; other villages are on rising ground bordering marsh land. On the Chalk hills and valleys are several small villages. On the slope of the chief wooded hill, on Tertiary Sands at 80 to 40 feet high, stands the large village of *Boughton-under-Blean. Harbledown,* at the extreme east, is a suburb of Canterbury, on the side of a hill of Tertiary Sands.

Approximate number of residents on alluvium 350; on London Clay without gravel, 480; on Lower London Tertiaries, 5,850; on Chalk, 12,187.

Phthisis death-rate for males	- - -	312
„ „ females	- - -	429.

In Faversham there is some ague, less of late years than before the period to which the above rates refer. But there was an increase in 1859.

[40.] RYE, Sussex. Acres, 39,369. Population, 11,927.
Maps 4 and 5.

Rye.

A district formed for the most part by the Hastings Beds of the Wealden. These consist of sands and clays (the area being about half sand, half clay and alluvium) with a long fault through them from east to west, and other smaller faults. This part is of good elevation and undulating, but river valleys with alluvium bound it on the north and south and partly intersect it. To the east a part of Romney Marsh is included in this district, with deposits of shingle on the coast.

Rye is on an island of Ashdown Sand surrounded by marsh, and rising 60 feet above the marsh; there is a little capping of clay on the surface. The higher parts must have good natural drainage. *Winchelsea* is on a peninsula of the same description, on a considerable rise with a cliff to the sea. Its situation appears to be dry. The marsh around these places consists of a flat of the Ashburnham Beds (sandy clays at the bottom of the Hastings series) covered by alluvium of estuary origin. Rye and Winchelsea, the chief places of the district, are close to the sea. Other places are *Northiam*, on sand above Wadhurst Clay, on a hill; *Beckly* and *Peasemarsh*, similarly placed but apparently farther from clay; and *Brede*, on Wadhurst Clay. The circumstances of the soil in these places is mostly favourable to the retention of water. The population of the district is largely seafaring.

Estimated number of population living on alluvium, 300; on shingle, 100; on clays of the Hastings series, 2,000; on the sands of the same, 9,471; and on board vessels there were 56 persons.

Phthisis death-rate for males	- - -	315
" " females	- -	438

There was once on a time much ague here, with an accession in 1859; less since then.

[42.] MAIDSTONE, Kent. Acres, 38,082. Population, 38,670.
Map 6.

Maidstone.

The northern part of this district is Lower Greensand, forming a tolerably high country, rising to the south, well drained, and intersected by the valley of the Medway. The southern part of the district is lower, 50 to 100 feet, and is of Weald Clay capped by gravel and loam over nearly half its area: this part is cut through by various rivers with alluvium along them; where there is gravel it is dry, but the rest is wet, and near Yalding is much subject to floods.

Of the town of *Maidstone*, more than half is placed on an inlier of Weald Clay and Atherfield Clay cut through by the Medway and another stream, and almost wholly covered by gravel. The highest part of the town is its triangular periphery of pervious Hythe Beds over Atherfield Clay. The soil of the lowest parts of Maidstone must be wet to the level of the river (which is here tidal); and other parts at the junction of the clay and pervious beds are also in a position to have their soil saturated. This may locally have been less since the adjacent railway cutting was made through the edge of the clay, when trouble arose through a brewery well having been dried by this work. *Loose* is a large village situated on a slope of the Hythe Beds, and on

APPENDIX.

No. 5. *On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.*

an inlier of Atherfield Clay without a river, and at a lower level than Maidstone. There are a few villages (of which *Brasted* is the chief) on other parts of the Lower Greensand district, but the chief remaining places are on the Weald Clay. Of these *Marden* has a good deal of gravel over the clay, and stands at some elevation; at *Staplehurst* there is less gravel; and part of *Yalding* stands on alluvium.

Approximate number of dwellers on alluvium, 300; on Lower Greensand, 16,700 (none to speak of being on the Sandgate Beds); on Weald Clay covered by gravel, 17,530; on the same without gravel, 4,140.

Phthisis death-rate for males	-	394
" " females	-	475.

Correction has been made in these rates for persons dying of phthisis in the Kent County Lunatic Asylum who had their previous residence beyond Maidstone, and the corrected rates are males, 354; females, 405.—Ague was common in this district, both in the town and villages, in 1859; at other times it has been rare. The year 1859 was particularly dry, "exposing surfaces to evaporation that commonly remained moist." The town was being drained in 1863.

[43.] CUCKFIELD, Sussex. Acres, 61,793. Population, 17,163. Maps 5 and 9.

Cuckfield.

A large rural district, thinly populated. The northern and larger parts is of sands and clays (mostly sands) of the Hastings Beds, much faulted. The Tunbridge Wells "Sands" are here much divided by clays and loams, and are overlain in places by patches of Weald Clay. The southern part is a vale of Weald Clay (low and wet), with Gault, Greensand, and Chalk at the extreme south.

Cuckfield, Lindfield, Slaugham, and a number of other places are on the Hastings Beds, mostly on the sandy members of the series. Cuckfield is a good instance of the variety of soil that is met with within a small area in these Hastings Bed districts. It stands on a double sandwich, as it were, of clay and sand; the highest clay being an outlier of Weald Clay, the other two sands and two clays being members of the Hastings Beds, and all much faulted. Thus, though the ground is high, it is impossible to say what part live on dry and what on wet soil. Certainly this town and most of the villages on the same formation must have many springs and much wet soil.—Villages on the Weald Clay area are near brooks, and are low and damp. *Hurstpierpoint,* on somewhat rising loamy sand of the Lower Greensand, and other places near the edge of the Weald, on the same formation, are also likely to be wet. Small places at the junction of Chalk and Upper Greensand stand quite well for dryness.

Estimated population living on Chalk, 550; on Upper Greensand, 360; on Gault, 30; on Lower Greensand, 2,910 (of whom perhaps 200 live on Sandgate Beds); on Weald Clay without gravel, 4,262; on the clays of the Hastings Beds, 850, and on the "sands" of the same series, 8,200.

Phthisis death-rate for males	-	304
" " females	-	471.

[44.] DORKING, Surrey. Acres, 40,006. Population, 12,445. Map 8.

Dorking.

On the north a small part of this district is high Chalk with local cappings of surface clay and loam. A narrow band of Upper Green-

sand and Gault, and a broadish band of Lower Greensand (represented here by pervious beds only) cross the district from east to west. The southern part, about half the area of the district, is Weald Clay, which forms as usual a wooded plain flat or with very slight undulations only, but at its junction with the Lower Greensand rises more sharply, and Leith Hill, formed by the Greensand over Weald Clay, is the highest ground of the south of England, reaching nearly 1,000 feet above Ordnance datum.

The town of *Dorking* is mainly on a slope of Lower Greensand, some of its lower parts being on gault covered by much gravel. The lower lying parts are but little above the saturation level of the Lower Greensand. Other places are similarly situated in a valley of this last formation. On the north are some villages at the junction of the chalk and Tertiaries, and others in the valley of the Mole on chalk. On the south there are many villages and hamlets on the Weald Clay area.

Estimated population on London Clay (without gravel), 100; on Lower London Tertiaries, 230; on Chalk, 1,020; on Upper Greensand and Gault (each), 50; on Lower Greensand (all sandy), 7,065; on Weald Clay, 3,930, of whom 100 live on spots that have gravel.

Phthisis death-rate for males	-	321
" " females	-	478.

[45.] UCKFIELD, Sussex. Acres, 74,230. Population, 17,260. Maps 5 and 6.

Uckfield.

A district wholly rural, and composed almost exclusively of Hastings Beds, much faulted, with more of the sands than of the clays of that series, in the proportion of about 4 to 1 of area. In the eastern part, however, the Tunbridge Wells Sand is loamy. The country rises to its highest ground (600 feet) on the north, and is much intersected by streams at levels of about 120 feet or thereabouts above datum. There is a very small piece of Weald Clay at the south-west.

Rotherfield and *Mayfield*, the two largest places, are on slight hills of Ashdown Sand and Tunbridge Wells Sand respectively. The former is well placed for natural drainage, but at Mayfield the sand may have water kept up in it by the underlying Wadhurst Clay. *Buxted* is placed much like Mayfield, and *Waldron* like Rotherfield. *Uckfield*, *Maresfield*, and *Fletching* are on slopes of sand near to streams. *Framfield* stands on a slight hill of Wadhurst Clay. On the whole, except for the retentive character that the Hastings Sands have in particular localities, this district would not be supposed to have much wet soil, at any rate in such parts as are most inhabited. It is difficult to see any serious difference in physical or geological features between Uckfield and Battle, which has a far smaller phthisis rate.

Approximate number of population living on alluvium, 60; on uncovered Weald Clay, 200; on clays of the Hastings Beds, 3,000; on sands of the same, 14,000.

Phthisis death-rate for males	-	312
" " females	-	484.

[46.] HAILSHAM, Sussex. Acres, 54,365. Population, 12,668. Map 5.

Hailsham.

A district high at the north, reaching 500 to 600 feet, but sloping down to the marsh of Pevensey Level at the south. The northern half is of Hastings Beds, which here are mainly sandy (Tunbridge Wells and Ashdown Sands), and sloping (Wadhurst) clay. The southern half is Weald Clay with marsh land.

Hailsham, the most populous place, is on a very slight rise of Weald Clay about a mile from the marsh ; other smaller places are also on the Weald Clay. *Herstmonceux* and *Worthing* are on a slight rise of sand, quite at the edge of the marsh, and have brooks all round them. *Heathfield* and *Warbleton* are high, on Ashdown Sand. Other places stand on other parts of Hastings Beds, or on the junction of these with Weald Clay.

Of the total population, it is estimated that 50 live on alluvium, 40 on Gault, 70 on Lower Greensand, 4,290 on Weald Clay without gravel, 500 on clays of the Hastings series, and 7,718 on the sands of the same series.

Phthisis death-rate for males - - -	270
„ „ females - -	535.

There is no known reason why the female rate should be in so very great excess of the male. But the same fact will be observed in most of the districts that have high rates.

[47.] TICEHURST, Sussex. Acres, 51,659. Population, 14,626.
Maps 5 and 6.

Ticehurst.

This district is entirely of Hastings Beds, nearly half being Wadhurst Clay. There is considerable range of elevation, from 600 feet at Frant to 250 at the north-west (where part of Tunbridge Wells town is in this district), and even to 50–100 feet on the south and south-east. The northern tract, which is the highest and most sloping, is (as regards all its inhabited parts) of Tunbridge Wells Sand. The southern has much wet clay soil, but is not flat or low.

Frant, just mentioned, is a large village, high and dry. *Ticehurst*, of like size, is partly on the Tunbridge Wells Sands, partly on Wadhurst Clay, and near a considerable fault. The surface of the clay is in slopes, but in the sandy parts water is probably held up. *Burwash* stands on an outlier of sand over clay, also on moderately high ground. It is the habit of clay so placed to form slight troughs or hollows, and to keep the porous soil over it wet. *Wadhurst* is at the junction of clay over sand, on a hill, and in a dry situation. *Lamberhurst* lies low, by a stream, on sand over clay, where there is some alluvium.

Estimated population on clays of the Hastings Beds, 4,800; on sands of the same, 9,826.

Phthisis death-rate for males - - -	346
„ „ females - - -	457.

There is a large private lunatic asylum here, but it does not affect the above death-rates.

[48.] WORTHING, Sussex. Acres, 42,457. Population, 18,921.
Map 9.

Worthing.

Consists mainly of Chalk, dipping slightly from the sea to the north, and also from the escarpment to the south. At the north a small part is Upper Greensand and Gault, and near the south a narrow strip of Tertiaries runs from east to west across the district. The whole is cut through from north to south by the river Arun, with a broad belt of alluvium, and some little gravel locally mixed with clay.

The Chalk at the northern part of this district makes, as usual with that formation, a high and sloping country, but the broad tract of chalk facing the sea, and upon which the bulk of the population reside, is largely covered by loam and gravel, and lies very low, only a few feet above high-water mark.

Worthing is the largest place, and stands on loam and clay over Chalk, the main part of the town on a flat of 18–20 feet elevation, and water used to be reached wherever a trench was dug. In 1853–6, soon after the beginning of the period to which the subjoined phthisis rates refer, sewerage works were carried out in Worthing with the effect of lowering the water-line under the town. *Littlehampton* and many other villages are on the same low-lying Chalk, with more or less surface gravel and brick-earth, at no great distance from the sea. At *Poling*, two miles from the coast, the Chalk has only risen to 20 feet above mid-level of the sea. On the higher-lying Chalk the chief place is *Arundel;* here the chalk is almost uncovered, and the town is on a considerable slope towards the river, part being on river alluvium. *Broadwater* is on a Chalk slope 48–32 feet high. Other villages are in the valley of the Arun, on gravel over low-lying Chalk, and others on the chalk just off the alluvial edge of the river. *Buxted* and *Amberley* are villages on the Upper Greensand, the latter being near a marsh.

Estimated population living on alluvium, 550; on blown sand (classed with shingle), 200; on Lower London Tertiaries, 420; on Chalk, 17,296 (the great majority being on the low gravel-covered plain); on Upper Greensand, 440; and there is a detached morsel, with perhaps 15 people, on Weald Clay.

Phthisis death-rate for males	- - -	393
„ „ females	- - -	445

Note that in the town of Worthing itself the mortality from consumption among residents at the ages of 15–55 has fallen since the sanitary operations of 1853–56: the degree of this reduction being for males 11, and for females 41 per cent. of the previously existing rate of mortality.

[49.] WEST ASHFORD, Kent. Acres, 41,901. Population, 15,137. Maps 3 and 6.

West Ashford.

The southern two-thirds of this district is formed by Weald and Atherfield Clay, mostly low and flat. The broad band of Lower Greensand which follows is here largely represented by the clayey Sandgate Beds. Then comes a narrow band of Gault, and at the northern extremity of the district a little Chalk. Perhaps not more than one-sixth of the area is formed by pervious beds.

The undulations of the Weald Clay country are shown on the line of the South-eastern Railway, from west to east, through this district. There is in the part of maximum range a difference of from 100 to 140 feet in the course of a mile, but the slopes are mostly about 20 feet in a mile, and are many and in varied directions, with streams in the lower ground.

Ashford town contains a third of the population of the district. It is on a slight rise of gravel underlaid by sands and clays of the Lower Greensand; directly outside the town, and on three sides of it, the Atherfield and Weald Clays crop out, and probably form a slight basin below the town. *New Ashford*, on the other side of the river Stour, is mostly on flat clay. *Charing* and *Westwell* are on a high level at the base of the Chalk escarpment, where the Chalk is apt to be marly, and its water to be held up by the underlying Gault. *Bethersden*, *Smarden*, and other villages are on the plain of Weald Clay, Smarden being on a small flat of gravel. Other places are on the Lower Greensand; a few scattered houses only are on Gault.

Approximate population on alluvium, 100; on Chalk, 1,267; on Gault, 400; on Lower Greensand, 7,490 (viz., 3,000 on clayey beds, and

4,490 on the sands of this series); on Weald Clay without gravel, 700; and on the same with some gravel, 5,180.

Phthisis death-rate for males - - -	300
„ „ females - - -	542.

[50.] LEWES District, Sussex. Acres, 85,104 Population, 26,995. Maps 5 and 9.

Lewes.

Four poor law unions are comprised within this district, which extends from the sea some eight miles or more inland, and along the coast for 10–12 miles. The southern half is chalk, rising into four masses of hill divided by valleys, three of which have tidal streams in them, bordered by considerable tracts of alluvium. Across the district, from east to west, bands of Upper Greensand, Gault, and Lower Greensand run, forming a low flat district very unlike the greensand areas to the north and west, and only moderately dry. Then follows on the north a vale of Weald Clay, flat and wet; and at the extreme north there is an area of Tunbridge Wells Sand, which slopes southward, and contains some loam and clay. This part is less dry than the similar bed farther to the east (Uckfield, &c.). Both the Gault and the Weald Clay are so arranged that they throw out the water from the Greensands over them.

The population is but little on the high Chalk; but many villages along the edge of alluvium, in the Ouse valley, are on Chalk; water must be near the surface in most of them. *Lewes*, by far the most populous place, lies at the junction of these Chalk valleys, on a sluggish river which is tidal up to a lock above the town. Part of the houses are on chalk, rising to 100–150 feet, but most on low-lying chalk covered by gravel and alluvium that must be waterlogged. *Newhaven* is situated much like Lewes, but close to the sea. *Ditchling* (observe the name) is on the flat Lower Greensand, mainly on Sandgate Beds. There are villages on all the other formations that are above described.

Number of population estimated to live on alluvium, 1,100; on chalk (mostly low and gravelled), 16,180; on Upper Greensand, 1,750; on gault, 250; on Lower Greensand, 2,250 (of whom 750 are on Sandgate Beds); on Weald Clay, 2,785 (of whom 30 may be on a little gravel; on Hastings Beds (all sandy), 2,680.

Phthisis death-rate for males - - -	496
„ „ females - - -	508.

Deduction from these rates is required for persons belonging to other districts who died of phthisis (1) in the Invalid Convict prison, 1857–59; and (2) in the Sussex Lunatic Asylum at Haywards Heath. Of the convicts 42 males, and of the lunatics 30 males and 30 females, have been taken out of the numbers on which the above rates are founded, and the corrected rates become—for males, 388; and for females, 464. There has been little ague in the town of Lewes of late years, but it has prevailed, during the period under review, at Glynde, Beddingham, Piddinghoe, and other places. Its reduction is ascribed to better drainage of land.

[51.] TENTERDEN, Kent. Acres, 46,889. Population, 10,947. Maps 3, 4, 5, 6.

Tenterden.

About three-quarters of the district consist of clay and alluvium, and one quarter of sand. The north-eastern part is Weald Clay, low, flat, and wet; the southern part is on the clays and sands of the Hastings

series, which are much faulted and intersected by rivers with alluvial flats, forming a country of very various elevations. Such river flats bound the district for more than half its circumference.

Tenterden is the largest place, having a third of the whole population. It is on a hill of sand, which is here very clayey (Tunbridge Wells Sand and Grinstead Clay), over a flat or slight trough of Wadhurst Clay. Another third of the population, in the villages of *Biddenden*, *High Halden*, and *Woodchurch*, is on Weald Clay; all those places lying flat, and more or less low. The remaining population is mostly on Hastings Beds. *Appledore* is on sands, close to the alluvium of Romney Marsh; and other villages, *Rolvenden*, *Wittersham*, and *Stone*, on Wadhurst Clay, at various small elevations.

Of the whole population, estimated number living on alluvium, 30; on Weald Clay without gravel, 3,200; on clays of the Hastings series, 3,200; on sands of the same, 4,517.

Phthisis death-rate for males	- - -	342
„ „ females	- - -	528.

[52.] HORSHAM, Sussex. Acres, 57,023. Population, 15,313.
Maps 8 and 9.

Horsham.

Chiefly an area of Weald Clay underlaid by Tunbridge Wells Sands, which come to the surface in the eastern part of the district. A local band of calcareous sandstone in the Weald Clay (Horsham stone) forms a higher and drier district than the general tract of clay; but this includes some clay, and is not so pervious as even the Tunbridge Wells Sand.

Horsham itself, with nearly half the population, is low and flat, on the loamy Tunbridge Wells Sands, close to where they dip under the clay. Other places are on the plain of Weald Clay, which has many gentle undulations in it, 100–200 feet above Ordnance datum, but no continuous slopes.

Estimated population on Weald Clay (without gravel, but locally with Horsham stone), 8,563; on the sandy parts of the same (which are particularly noted as "loamy," though no population can be separated out as living on clays), 6,750.

Phthisis death-rate for males	- - -	362
„ „ females	- - -	518.

[53.] WESTHAMPTNETT, Sussex. Acres, 74,913. Population, 14,811.
Maps 9 and 11.

Westhampt-nett.

Consists of (1) a northern part, less than half the area, of bare chalk rising to high ground (700 feet), and then sloping sharply downwards to the northern boundary, where the Gault and Lower Greensand crop out; and (2) of a southern part of clayey Lower London Tertiaries, London Clay, and Bracklesham Beds (the middle and clayey division of the Bagshot), with a spur of chalk, forming a low ground more or less covered by gravel and loam, and intersected by streams with alluvium along them. Selsea is on the Bracklesham Beds, with gravel, which here are formed into an island by the sea on one side, and on the other by a stream and its low alluvial border.

About half the population lives on the low flat plain of Tertiaries near the sea. This plain appears, from such sections and elevations as can be had, not to rise more than 10 feet above the mid-level of the sea, and in many parts to be under high-water mark. Three or four miles inland the Tertiaries, rising to about 80 feet where they join the chalk, have several more villages on them, and there are others adjacent, on

the rising chalk with gravel. The higher chalk is very thinly inhabited, but there is a village on Upper Greensand and Gault. Of 39 places in the district not one has a population so large as 1,000.

Of total population, estimated residents on alluvium, 120; on Bracklesham Beds of the Bagshot series, 1,570; on gravel over London Clay, 4,120; on Lower London Tertiaries, 3,910; on Chalk, 4,711; on Upper Greensand, 120; on Gault 230; and on Lower Greensand, 30.

Phthisis death-rate for males - - -	366
" " females - - -	518.

Corrected for the deaths of persons who, after removal from this district, died in the Chichester Infirmary, these rates become—for males, 377; females, 521.

[54.] MIDHURST, Sussex. Acres, 65,720. Population, 12,581. Maps 8 and 9.

Midhurst.

A district formed partly by Weald Clay, at the extreme west end of the Weald district, but in its larger part by Lower Greensand, Gault, Upper Greensand, and Chalk. Taking the clays of the Weald and Gault, together with the clayey parts (Sandgate Beds) of the Lower Greensand, about half the area is on impervious beds, all of which form tolerably flat surfaces; and the other half on Greensands (sand and stone) and Chalk, which last forms high ground on the south.

Midhurst is a small town which, with many smaller villages, lies on the river Arun, on rather low ground formed by Lower Greensand, and principally by the clayey division thereof. The ground slopes, indeed, towards the stream, but is certainly spongy and wet. A line of villages, of which *South Harting* is the chief, lie on the Upper Greensand, some nearer to Chalk, others to Gault, most with springs near them. Some of these places may be wet. Two small places are on Gault, others on slight slopes of Weald Clay.

Estimated population on alluvium, 20; on Chalk, 410; on Upper Greensand, 1,770; on Gault, 200; on Lower Greensand, 6,681 (of whom 3,500 is the probable number of residents on Sandgate Beds); on Weald Clay without gravel, 3,500.

Phthisis death-rate for males - - -	372
" " females - - -	539.

[55.] THAKEHAM, Sussex. Acres, 33,599. Population, 7,567. Map 9.

Thakeham.

The district is very various in its contour and geology. The southern third, the high part of it, is Chalk, a third Gault and Lower Greensand, and a third to the north is Weald Clay; the centre of the district is an alluvial flat. The Chalk rises to a hill of 800 feet, and is everywhere scantily inhabited. North of the chalk escarpment is a plain of Upper Greensand, Gault, and Lower Greensand, the last being chiefly represented by its clayey (Sandgate) member. It is part of this plain that is covered by alluvium. Then northward follow the Hythe Beds, sandy and calcareous parts of the Lower Greensand, sloping again gently downward; the Weald Clay then makes a second almost flat plain, about 70 feet above datum.

Pullborough is the largest village, and is on the pervious Folkestone Beds of the Lower Greensand, but at a low level, with clayey beds below, and at the edge of the marsh. Other places are similarly situated,

some even upon more gravelly spots of alluvium. *Storrington*, the second largest place, is on the same beds, but farther from the marsh. *Thakeham* and some other villages are on the Hythe Beds. At the two extremes there is a scattered population on chalk and on Weald Clay.

Estimated population on Chalk, 710; on Upper Greensand, 540; on Gault, 635; on Lower Greensand, clayey beds, 1,100, sandy beds, 3,290; on Weald Clay, without any gravel, 1,294.

Phthisis death-rate for males - - -	348
„ „ females - -	560.

[56.] PETWORTH, Sussex. Acres, 39,329. Population, 9,397. Maps 8 and 9.

Petworth.

A district wholly of Weald Clay, except a small part in the south-west corner, on which *Petworth* town, with about a third of the population of the district, stands. This is the calcareous part (Hythe Beds) of the Lower Greensand, fairly high and dry, and draining to a stream. All the rest of the district is low, flat, and wet.

Approximate number of residents on Lower Greensand (only sandy beds), 2,850; on Weald Clay without gravel, 6,547.

Phthisis death-rate for males - - -	415
„ „ females - -	509.

[57.] WESTBOURNE, Sussex. Acres, 32,886. Population, 6,957. Maps 9 and 11.

Westbourne.

Consists of two tracts of Chalk, and two of Tertiaries, alternating. The northernmost part is high-lying chalk (500 feet), but the Tertiaries, and the band of chalk between them, form a flat plain of 15–25 feet above Ordnance datum, covered by gravel and bordered by a creek. All this part must be thoroughly wet.

Westbourne is on London Clay and Woolwich Beds, rising slightly from a stream. *Borham* and *Chidham* are very low, near to creeks, on gravel-covered Chalk. *Funtington* and other villages, together including nearly half the population, are on dry high Chalk.

Approximate number of residents on London Clay (without gravel), 1,000; on Lower London Tertiaries, 1,697; on Chalk, 4,260.

Phthisis death-rate for males - - -	386
„ „ females - -	610.

The population of this district is such, that one death more or less each year represents a difference of 56 in the above rate for males and 58 in the rate for females.

[58.] CHICHESTER District, Sussex. Acres, 21,054. Population, 14,775. Map 9.

Chichester.

This district consists of several areas scattered about among other districts. The two chief areas are (1) that of Chichester city and its environs, and (2) the Sutton area. The former is low-lying London Clay and Reading Beds, capped by gravel and loam, with a slope within the city from 49 to 21 feet; the latter is mainly Lower Greensand, also Gault, Upper Greensand, and Chalk; and the valley of the Arun runs through it. Other areas comprise (3) *Bognor*, on low gravel-covered clay, and adjacent parts on low flat chalk; (4) *Bury*, on Upper Greensand, near a marsh; (5) *Greatham*, on gravel over Lower Greensand; (6) *Heyshott*, on almost flat gault.

Approximate number of residents on gravel-covered London Clay, 10,210; on Lower London Tertiaries, 1,550; on chalk, 300; on Upper Greensand, 1,000; on gault, 720; and on Lower Greensand, 995 (700 of whom are on Sandgate Beds).

Phthisis death-rate for males	- - -	670
" " females	- -	463.

Corrected for deaths in the Chichester Infirmary of patients brought from other districts, these rates become—for males 623, for females 450.

Districts that can hardly be classified.

Sheppey.

[1 ? ?] SHEPPEY, Kent. Acres, 31,083. Population, 18,494. Maps 2 and 3.

This district, which has by far the lowest registered phthisis death-rate of any in the south-eastern counties, is an island of London Clay, capped by gravel and Bagshot Sand on its highest levels, and bordered on the south and west by alluvium, with islets of London Clay rising out of it. The London Clay, which forms the bulk of the district, rises to about 150 feet, and forms sloping ground, except where it is covered at the highest parts by gravel and at the lowest by alluvium.

Sheerness contains two-thirds of the population of the district. It lies very low, at the extreme north-west point of the island, almost on the level of the Medway, on a plain of alluvium 8–9 feet thick, below which shingle is generally met with. This alluvium is a softish clay; if a trench be dug in it, brackish water generally rises to within a few inches of the surface. In Sheerness is the dockyard, which gives an exceptional sort of employment to the male population; here, too, are barracks, and a number of persons are enumerated on board vessels. *Queensborough* resembles Sheerness in its position, but is placed slightly higher, on a low island of London Clay. The parts of Minster parish beyond *Sheerness* town, and *Eastchurch*, *Leysdown*, and *Warden*, are villages on high ground, most, if not all of them, being on cappings of gravel or sand over the London Clay. Such sites are often retentive of wet, from the surface of the clay being slightly basin-like, but in these instances the edge of every such basin is more or less broken by the sea cliff.

Approximate number of the population of the district living on alluvium, 12,069; on Bagshot Beds, 1,000; on gravel over London Clay, 50; on London Clay without gravel, 3,800; on board vessels, 1,575.

Phthisis death-rate (registered) for males	-	202
" " " females	-	251.

Sheppey is a district for which the method of computation in the Parliamentary return gives inaccurate results. The population is rapidly increasing, and the arithmetical mean of the two censuses, from which the death-rate is calculated, is larger than the true mean upon which the death-rate ought to be taken. (See note to Kingston.) The death-rate therefore comes out unduly low. The census papers give evidence of considerable importation of males from 15 to 45 years old, and of some exportation of them after the latter age, a large proportion of the incomers being unmarried. The presumption is, that these people are of the healthier sort, and that if they were unable to work they would go away from the district to be nursed. Local information confirms the conclusion that the phthisis rate of males is thus artificially lowered.

The female rate is probably influenced in the same direction, but to a much less degree, by similar considerations. It is pretty clear that many females also spend only the middle period of their lives here, probably coming and going with their husbands, and in case of illness returning to their previous residence.—The military at Sheerness numbered 752, and with their wives and families 1,005, in 1861. They are treated when sick in the hospital attached to their barracks, but if they get phthisis are often discharged invalided and die in other districts. So far as they died in the hospital, their phthisis rate is just that registered for males in the district at large.

Ague was prevalent in the Isle of Sheppey during the period 1851–60. Of late years it has been reduced in Sheerness. At Minster and Eastchurch it remains about as common as formerly. Local medical opinion assigns less phthisis to Sheerness than to the other places where there is more ague.

[2 ? ?] HASTINGS, Sussex. Acres, 14,027. Population, 26,631. Map 5.

Hastings.

The district is from 300 to 400 feet high in its central parts, and the ground forms three hills with deep valleys running to the sea. It comprises the towns of *Hastings* and *St. Leonards* only. They lie on the lower beds of the Wealden series, which are grouped under the name of "Hastings Beds," and consist of alternations of sand and clay; in this case the area of the district being about two-thirds of sand and one-third of clay. The Castle Hill is Ashdown Sand, on which also the main parts of the town of Hastings are built. St. Leonards is chiefly on the Tunbridge Wells Sand, and partly also on Wadhurst Clay. There is great range of elevation within the inhabited parts of this town, and there must be very varying facilities for the natural drainage of particular parts, considering that some localities stand high, some low; most on sands, but some on clay. But the most parts must be dry.

Of the population about 1,300 only are estimated to live on the clays of the Hastings Beds, the remainder on sand.

Phthisis death-rate (registered) for males	-	531
" " " females	-	466.

Enquiry has been made by Dr. Greenhill, of Hastings, as to the mortality among persons frequenting this town on account of the repute its climate has obtained in consumption, and the result is that certainly more than half the registered mortality from this disease is among visitors. Of the male rate, 288 is accounted for by visitors, and of the female rate 259, reckoning the deaths on the male and female population aged 15–55, mean of two censuses. But as the numbers of visitors have not been ascertained at the censuses, the rate among residents cannot be computed by merely deducting these figures. Perhaps half the registered rates will be not far from the truth for consumption among residents. Its indigenous phthisis only would certainly place Hastings in a wholly different place among other districts than is assigned to it for its registered mortality from the disease. But of its true position relatively to other districts, it can only be affirmed that it must stand among the highest, perhaps even in the very highest place.

[8 ? ?] THANET, Kent. Acres, 29,733. Population, 31,862. Map 3.

Thanet.

Bounded for three-quarters of its extent by sea, and formed into an island by the Stour and Wantsome rivers, which are flanked by broad

marshes. Nearly the whole island is bare Chalk, with a foot or so only of loamy soil above it. Here and there are small patches of clayey Thanet Beds, and the edge of the marsh on the south is fringed by a thicker mass of this formation, consisting of sand and sandy marl.

Ramsgate is cut through by a valley running to the sea, with coarse gravel covering the Chalk at the bottom. On the western heights is a small capping of sandy brick-earth. Its elevations range from 125 to 16 feet above the mid-level of the sea. *Margate* is similarly placed, but a small part is on a flat of alluvium which runs inland from the harbour. With the exception of this part and some portions of the valley at Margate, there is excellent natural drainage of the subsoil in both towns. The range of altitude in Margate is from 150 to 14 feet. *Broadstairs* and the main area of the district are high and dry, on the Chalk. *Minster*, a large village, is on marly Thanet Sand and brick-earth at the edge of the marsh, in a wet situation.

Approximate number of residents on alluvium, 100; on Lower London Tertiaries, 1,300; on Chalk, 30,462.

Phthisis death-rate for males	-	420
„ „ females	-	364.

These death-rates are both somewhat raised (the male most so) by the presence of two infirmaries at Margate; but they are both further raised, to a great and unascertainable extent, by the practice of sending consumptive invalids to Margate in the late stages of their complaint. A letter from Dr. Price, of Margate, gives data which prove that 100, and probably more, should be deducted from each of the above figures for deaths among persons previously unconnected with the district.

[14 ? ?] HOO, Kent. Acres, 33,281. Population, 2,861. Maps 1 and 6.

Hoo.

A very thinly populated district between the Thames and Medway, consisting of London Clay with local gravels, with an insignificant area of sandy Lower London Tertiaries cropping out on the north-west. The district has various elevations and slopes, its highest point being 200 feet; thus there will be fair surface drainage. On the north and east the district is bordered by marsh.

Hoo is the chief place, though only a village. It is on a thick bed of brick-earth and gravel, with a fair slope.

Of the whole population 80 may be taken as living on alluvium, 1,851 on London Clay with gravel, 750 on London Clay without gravel, and 180 on Lower London Tertiaries.

Phthisis death-rate for males	-	226
„ „ females	-	376.

Note that very few actual deaths would make great difference in these rates, so great a difference that no conclusion can be drawn from the figures. There was a good deal of ague during almost the whole of the period 1851–60, but towards the latter date improved tillage had got rid of much of this disease.

[23 ? ?] TUNBRIDGE, Kent. Acres, 46,179. Population, 34,271. Map 6.

Tunbridge.

This is a Wealden district, about two-thirds of which are clay and one-third sand. The north-eastern part is Weald Clay, mostly covered by thin loam and gravel, and intersected or bordered by streams with alluvium. This part has an average (pretty uniform) elevation of 100–150 feet, but the Weald Clay has a greater range of height in

particular places, 250 feet and 50 feet being the extremes. The larger part consists of sands and clays of the Hastings series, in irregular tracts and a good deal faulted, and rising to high ground (500 feet at Tunbridge Wells), the highest parts being often formed by outliers of Weald Clay, the lowest by Wadhurst Clay, and the intermediate slopes by Tunbridge Wells Sand. In this last sand a band of clay (Grinstead Clay) occurs, but not in quantity enough to affect materially the dryness of the sand.

The town of *Tunbridge Wells* is the largest in the district. It stands mainly upon the highest member of the Hastings Beds, to which it gives a name. A northern part of the town is on an outlier of Weald Clay at good elevation. There is a slope in the town of at least 70 feet. *Tunbridge* town is mainly on gravel over Weald Clay, but on the south there are houses on alluvium (often flooded), and a good many on gravel over Tunbridge Wells Sand and Wadhurst Clay. There is a slope of 40 to 50 feet in the town, but parts are flat, especially those to the south of the town. *Hadlow* is a large village on a flat of Weald Clay, covered by gravel and loam. There are other villages in the district, mostly on the Tunbridge Wells Sand at its junction with Wadhurst Clay, but they are of no importance by the side of the large places named. The southern part of the section described under Sevenoaks will give a good notion of this country also.

Of the population of Tunbridge district it is estimated that 200 live on alluvium, 8,312 on the thin gravels that cover the Weald Clay, 2,413 on uncovered Weald Clay, 21,946 on the more sandy parts of the Hastings Beds, and 1,400 on the clays of that formation.

Phthisis death-rate (registered) for males	-	362
" " " females	-	437.

Tunbridge is one of the districts of which the exact phthisis rate among residents is uncertain, on account of many consumptive invalids resorting to Tunbridge Wells. Not much less than half the consumption deaths of that town (in the brief and recent experience of a registrar who has supplied information) have been among visitor invalids. Allowance being made for the special circumstances of this town in the figures relating to the whole district, the figures 302 for the male death-rate and 364 for the female, are suggested as a fair approximation to the true rates among residents.

[27 ? ?] MEDWAY, Kent. Acres, 14,565. Population, 51,805.
Map 6.

Medway.

A Chalk district, bordered on the north and west by the Medway and its narrow marshes. The general slope of the ground is in the main downwards from south to north and also from east to west. At the north-eastern edge of the district there is a little Tertiary sand.

Chatham and *Rochester* are by far the most important places of the district, which indeed contains little else than these towns and their suburbs. They lie on slopes of Chalk, rising to 200 feet in one direction and to 108 in another. These slopes are overlaid at *Brompton* (part of Chatham) by Thanet Sand. The Luton valley, which is covered by the houses of Chatham, has some gravel and brick-earth over its dry chalk bottom; but at the lowest parts of Rochester and Chatham, near the Medway, there is some alluvium over very low-lying chalk (the elevation of these parts above mid-level of the sea being only 18–20 feet), and here alone could there be any wetness of the superficial soil. *Gillingham* is on gravel over Thanet Beds.

APPENDIX.

No. 5.
On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.

Approximate number of residents on alluvium, 1,000; on Lower London Tertiaries, 5,000; on Chalk, 44,887; and there were at the census 918 persons on board vessels.

Phthisis death-rate (registered) for males	-	607
" " " females	-	353.

The male death-rate is greatly affected by the presence of a number of military and naval establishments in the district. The army and navy medical departments have kindly procured for this report several data which prove conclusively the great extent to which this disturbance goes; but as all the establishments of the district cannot be examined, it remains impossible to procure such corrections as would allow the true phthisis rate of ordinary male residents to be computed. The female phthisis death-rate has, therefore, been taken as the basis of an estimate of what the mean rate of the two sexes would be if the male population were not subject to disturbing influences; yet much uncertainty must remain as to the exactness of this estimate. At Chatham and Rochester there is little or no intermittent.

[31 ? ?] ROMNEY MARSH, Kent. Acres, 46,785. Population, 5,708. Map 4, with memoir.

Romney Marsh.

Except a few houses at *West Hythe* that are on Weald Clay, all the district is marsh land and shingle, almost the whole is "below the level "of high water at spring tides, but the access of the sea is prevented by "tracts of shingle bordering the marsh, which are partly piled above "the level of high water, and by artificial walls which have been "erected where no barrier of shingle exists. The patches of blown "sand consists of irregular hillocks, generally less than 20 feet high." (Geol. Survey, memoir, p. 15.) The marsh, which is formed by peat and clay with occasional sand hillocks, is underlaid at a depth of 10–20 feet by loose sand of unknown thickness, which furnishes the water supply.

Lydd and *New Romney* are the only places of any size. Both are on shingle, along a former coast line bordered closely by marsh land, but the inhabited parts are all on shingle rising somewhat above the marsh level; many coastguard stations are on the shingle. *Dymchurch* is on the present coast, on the marsh, and lies very low. All the rest of the district is on the marsh land just described.

Of the whole population 2,849 may be taken as living on alluvium and 2,829 on shingle, and 30 on uncovered Weald Clay.

Phthisis death-rate for males	-	-	315
" " females	-	-	381.

The smallness of population forbids much reliance to be placed upon these figures.

In this district there used to be much intermittent, described as peculiar in a way that suggests its being frequently a complication of typhoid fever. There is less ague of late years, and what is seen is described as being more like than it was to the disease elsewhere met with.

[41 ? ?] BRIGHTON, Sussex. Acres, 2,320. Population, 77,693. Map 9.

Brighton.

This district comprises the town within the municipal limits. Note that Hove is in Steyning district. The town is in its greatest part on slopes and in a valley of almost bare chalk; but some western parts are on an irregular accumulation (the elephant bed) of chalk-rubble and flints, quite as pervious as chalk itself; and along the valley there is a

APPENDIX.

No. 5.
On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
1, 6	3. Dartford - -	32,316	8	—	—	—	0·	43β	49	—	—	—	—	—	—	β On pervious.
8	4. Epsom - -	22,409	—	—	—	11	13	38β	38	—	—	—	—	—	—	β Some on impervious.
3, 6	5. Milton - -	14,775	3	—	—	2	5	51β	39	—	—	—	—	—	—	β Mod. pervious.
6, 8	6. Godstone - -	9,642	—	—	—	—	—	—	23	1	0·	59γ	5	11	1	γ On pervious.
1, 6	7. North Aylesford -	19,121	1	—	—	—	—	18β	81	—	—	—	—	—	—	β Mainly on pervious.
3	9. Dover - -	31,575	6	25	—	—	—	—	69	—	—	—	—	—	—	—
1, 6	10. Bromley - -	20,368	2	—	—	—	5	76β	17	—	—	—	—	—	—	β Mainly on pervious.
9	11. Steyning - -	24,053	1	—	—	—	—	—	80	7	0·	8γ	—	4	—	γ Part on impervious.
8	12. Chertsey - -	18,642	2	—	69α	29	—	—	—	—	—	—	—	—	—	α 56 on pervious; 13 on impervious.
6, 8	13. Croydon - -	46,474	0·	—	—	35	26	21β	18	—	—	—	—	—	—	β On pervious and impervious; artificially dried.
5, 6	15. Cranbrook - -	13,412	—	—	—	—	—	—	—	—	—	—	1	6	93δ	δ 84 on pervious; 9 on impervious.
7	16. Richmond - -	18,802	—	—	—	94	6	—	—	—	—	—	—	—	—	—
7, 8	17. Kingston - -	36,479	—	—	4α	79	17	—	—	—	—	—	—	—	—	α On pervious.

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Percentage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
3, 4	18. Elham - -	26,925	1	—	—	—	—	—	15	—	10	65γ	—	9	—	γ 61 on pervious; 4 on impervious.
3	19. Blean - -	16,161	13	4	—	6	36	41β	—	—	—	—	—	—	—	β Mod. pervious.
3	20. Bridge - -	11,316	4	—	—	0·	—	33β	63	—	—	—	—	—	—	β Mostly on pervious.
1, 6	21. Gravesend - -	18,782	0·	—	—	—	—	21β	75	—	—	—	—	—	—	Others on shipboard; β on pervious and impervious.
5, 6, 8, 9	22. East Grinstead -	14,097	—	—	—	—	—	—	—	—	—	—	—	12	88δ	δ 82 on pervious; 6 on impervious.
8	24. Reigate - -	20,109	—	—	—	—	0·	2	7	5	1	52γ	22	10	—	γ 47 on pervious; 5 on impervious.
5	25. Eastbourne -	10,721	1	2	—	—	—	9β	47	30	—	0	—	1	10	β On pervious.
8, 9	26. Farnham - -	30,707	1	—	67α	—	10	—	1	0·	9	12γ	—	—	—	α Mainly on pervious; γ pervious.
8, 9	28. Hambledon - -	13,907	—	—	—	—	—	—	—	—	—	49γ	20	31	—	γ On pervious.
5	29. Battle - -	12,680	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 80 on pervious; 20 on impervious.
3	30. Canterbury - -	16,643	10	—	—	—	—	18β	72	—	—	—	—	—	—	β On pervious.
3, 6	32. Hollingbourn -	13,584	—	—	—	—	—	—	32	—	9	37γ	4	18	—	γ On pervious.
6	33. Malling - -	21,447	0·	—	—	—	—	—	13	—	8	62γ	10	7	—	γ On pervious.
3, 4	34. East Ashford - -	12,286	2	—	—	—	—	1	30	—	20	25γ	—	20	2	γ 2β on pervious; 5 on impervious.
6	35. Sevenoaks - -	22,039	0·	—	—	—	—	—	8	2	4	47γ	5	17	17δ	γ On pervious. δ 12 on pervious; 5 on impervious.

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No. 5, *On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.*

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
8	36. Guildford - -	29,330	1	—	19α	7	9	5β	28	0·	0·	30γ	1	0·	—	α 15 on pervious; 4 on impervious. β On impervious. γ On pervious.
8, 9	37. Farnborough -	14,318	1	—	60α	—	9	0·	—	—	1	29β	—	—	—	α Mainly pervious. β Pervious.
3	38. Eastry - -	25,900	2	21	—	—	—	27β	50	—	—	—	—	—	—	β Mainly pervious.
3	39. Faversham - -	18,867	2	—	—	—	3	31β	64	—	—	—	—	—	—	β Mainly pervious.
4, 5	40. Rye - - -	11,927	3	1	—	—	—	—	—	—	—	—	—	—	96δ	δ 79 on pervious; 17 on impervious.
6	42. Maidstone - -	38,670	1	—	—	—	—	—	—	—	—	43γ	45	11	—	γ Pervious.
5, 9	43. Cuckfield - -	17,163	—	—	—	—	—	—	3	2	0·	17γ	—	25	53δ	γ 16 on pervious; 1 on impervious. δ 48 on pervious; 5 on impervious.
8	44. Dorking - -	12,445	—	—	—	—	1	2	8	0	1	56γ	1	31	—	γ Pervious.
5, 6	45. Uckfield - -	17,260	0·	—	—	—	—	—	—	—	—	—	—	1	99δ	δ 82 on pervious; 17 on impervious.
5	46. Hailsham - -	12,668	0·	—	—	—	—	—	—	—	0	1	—	34	65δ	δ 61 on pervious; 4 on impervious.
5, 6	47. Ticehurst - -	14,626	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 67 on pervious; 33 on impervious.
9	48. Worthing - -	18,921	3	1	—	—	—	2	92	2	—	—	—	0·	—	—
3, 6	49. West Ashford -	15,137	0·	—	—	—	—	—	8	0	3	50γ	5	34	—	γ 30 on pervious; 20 on impervious.
5, 9	50. Lewes - -	26,995	4	—	—	—	—	—	60	7	1	8γ	0·	10	10δ	γ Impervious. δ Pervious.

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Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks: chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
3, 4, 5, 6	51. Tenterden - -	10,947	0·	—	—	—	—	—	—	—	—	—	—	29	71δ	δ 42 on pervious; 29 on impervious.
8, 9	52. Horsham - -	15,313	—	—	—	—	—	—	—	—	—	—	—	56	44δ	δ "Loamy sands."
9, 11	53. Westhamptnett -	14,811	1	—	10α	28	—	26β	32	1	2	0·	—	—	—	α Impervious. β Mainly on impervious.
9, 11	54. Midhurst - -	12,581	0·	—	—	—	—	—	3	14	2	53γ	—	28	—	γ 25 on pervious; 28 on impervious.
9	55. Thakeham - -	7,569	—	—	—	—	—	—	9	7	8	59γ	—	17	—	γ 45 on pervious; 14 on impervious.
8, 9	56. Petworth - -	9,397	—	—	—	—	—	—	—	—	—	30γ	—	70	—	γ Pervious.
9, 11	57. Westbourne - -	6,957	—	—	—	—	14	24β	62	—	—	—	—	—	—	β Mainly impervious.
9	58. Chichester - -	14,775	—	—	—	69	—	10β	2	7	5	7γ	—	—	—	β Mainly impervious; gravelled. γ Gravelled.
2, 3	1 ??. Sheppey - -	18,494	65	—	6α	0·	21	—	—	—	—	—	—	—	—	Others on shipboard. α Pervious.
5	2 ??. Hastings - -	26,631	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 95 on pervious; 5 on impervious.
3	8 ??. Thanet - -	31,862	0·	—	—	—	—	4β	96	—	—	—	—	—	—	β Mod. pervious.
1, 6	14 ??. Hoo - - -	2,861	3	—	—	65	26	6β	—	—	—	—	—	—	—	β Pervious.
6	23 ??. Tunbridge -	34,271	1	—	—	—	—	—	—	—	—	—	24	7	68δ	δ 64 on pervious; 4 on impervious.
6	27 ??. Medway - -	51,805	2	—	—	—	—	10β	86	—	—	—	—	—	—	Others on shipboard. β Mod. pervious.
4	31 ??. Romney Marsh -	5,708	50	49	—	—	—	—	—	—	—	—	—	1	—	—
9	41 ??. Brighton - -	77,693	—	—	—	—	—	—	100	—	—	—	—	—	—	—

thickish bed of made earth, underlain by a flinty conglomerate known as Combe Rock. These are pervious, though less so than the chalk. At the lowest lying parts of the town the water-line is about 20 feet below the surface.

Phthisis death-rate for males	- - -	499
„ „ females	- - -	372.

These rates, but especially the male rate, are slightly raised by deaths in the Sussex County Hospital here; for practical purposes, however, this need not be considered. A more important disturbing influence (whose amount cannot at all be ascertained) is the use of Brighton as a place of residence for consumptive invalids; or the converse disuse of the town by residents who there become consumptive.

Summary view of connexion between soil and consumption.

IN the preceding table, so much of the geological account of each district is reproduced as relates to the formations on which people live, and the general perviousness or imperviousness of the soil may be learnt. The first impression from the table perhaps is that any of the great formations (with the exception of Weald Clay) may have on them a large share of the population of a district, and yet that district may have any position in respect of its phthisis mortality. But on looking into the list of districts (after a separate study of each) with special reference to the point suggested by last year's inquiry, the wetness or dryness of soil, it soon appears that the districts arranged in the order of the prevalence of consumption in them are also to a very great extent arranged in the order of the dryness or wetness of their soils.

It would be desirable, in proceeding to examine this point, to place the districts in a series according as each had fewer or more people living on wet or on dry soil. But it is impossible to do this on account of the want of universal comparability in respect of dryness and wetness between the soils of different formations, and even between soils made by the same formation in different geographical conditions. Thus the water-holding power of a soil is determined first by its degree of perviousness; and this, to begin with, is not the same throughout the whole extent of each bed, and still less can perviousness or imperviousness be taken as absolute terms to indicate that all pervious beds are exactly comparable together, or that one impervious bed is just as impervious as another. Secondly, the water-holding power of porous soils of equal permeability is determined in the main by different considerations than those which settle the water-holding powers of retentive soils of equal impermeability. In the former case, elevation, slope of subjacent beds, and other conditions indicating facility for water running away have chief weight in determining its wetness or dryness; in the latter case, of retentive soils, every consideration yields to the paramount one of surface slope. The difficulty of stating the precise order, as to dryness or wetness, of soils so various appears insuperable.

But though it is impossible to make the desired classification of all the districts, and although the evidence concerning the influence of soil is after all best shown by the detailed study of the particular districts, there are two ways in which the results of this inquiry may be summarized so as to present the facts in a prominent way. The one (A.) is to take groups of the districts in the order in which they stand for phthisis, and examine these groups as to the general perviousness or imperviousness of soil, trusting to other considerations of elevation, slope, &c.,

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compensating each other within the group. This is, upon merely arithmetical grounds, an objectionable method, for all the facts concerning a particular district get overlaid by those affecting other districts; absolutely negative cases get concealed; and thus the groups cannot safely and profitably be contrasted. The other method (B.) is to select out of the 58 districts such as are most comparable with each other in regard of their position and geological structure, and to see how their phthisis is affected by the perviousness or imperviousness, elevation or lowness, slope or flatness in the members of such more limited series.

Summary obtained by grouping.

(A.) Upon the method of grouping districts it was attempted to make a rough grouping of soils, according as they were retentive or pervious, for comparison with the prevalence of phthisis in the group. The 50 districts whose true mortality from the disease is pretty well ascertained were divided into five groups, the first group A having the 10 districts with the smallest phthisis rates, group B having the next smallest, and so on to group E, the 10 worst districts for consumption. Then for each group of districts the people living on pervious soils and those living on retentive soils were reckoned up, and a small intermediate group was made of such soils whose conditions appeared to entitle them to a middle place.

The following table was thus obtained:—

	Group A.	Group B.	Group C.	Group D.	Group E.
In groups, each of 10 registration districts, having population as shown, the numbers of residents on various formations are as below:—	219,516	205,610	186,941	188,395	134,482
Shingle and sea sand	8,000	900	—	5,800	—
Gravels over London Clay	8,036	63,526	2,200	—	14,330
Bagshot Beds, excluding tracts of Bracklesham	9,442 2,400	1,300	33,527	—	—
Lower London Tertiaries *	48,560	25,441	4,500	13,364	7,157
Chalk	96,057	36,326	33,033	44,143	27,838
Upper Greensand	1,620	—	580	850	5,180
Lower Greensand, excluding Sandgate Beds	25,010	14,210	54,619	26,745	17,086
Sandy members of the Hastings Beds	70	23,939	12,944	49,215	13,947
Per 1,000 of total population of the group living on these mostly pervious formations	**897**	**806**	**757**	**744**	**636**
London Clay, without gravel	4,903	24,905	7,090	580	1,000
Weald Clays, with gravels	500	4,489	7,040	17,630	730
Per 1,000 of total population of the group living on these formations of intermediately retentive character	**24**	**142**	**76**	**96**	**12**
Alluvium	6,525	3,084	2,880	2,070	1,370
Bracklesham Beds of Bagshot	2,400	—	? 1,000	—	1,570
Gault	2,763	240	9,105	120	2,435
Sandgate Beds of Lower Greensand	1,000	600	600	—	7,600
Weald Clays, without gravels	4,580	4,550	14,323	16,728	31,039
Clayey members of the Hastings Beds	—	2,100	3,600	11,150	3,200
Per 1,000 of total population of the group living on these retentive formations	**79**	**52**	**167**	**160**	**352**

* Lower London Tertiaries contain impervious beds, the population on which cannot be numerically separated; but as these are most of such beds in districts grouped E, the effect of separating them would apparently be to intensify the differences here shown between the groups.

Comparison of the five groups of districts shows a much larger proportion of residents on retentive soil in the 10 worst phthisis districts than in the 10 best, and if (by way of allowing for the intermediate character of the generally sloping London Clay and slight gravels on Weald Clay) we divide the middle class equally among pervious and retentive soils, we have the following series:—

Groups of Districts.	On Pervious Soils.	On retentive Soils.
A, with least phthisis -	- 909	91
B, with next least phthisis	- 877	123
C, middle as to phthisis	- 795	205
D, with still more phthisis	- 792	208
E, with most phthisis	- 642	358

But besides the arithmetical objections to which such a method as this is open, it is plain that, if retention of water in a soil be an influence upon consumption, a district has no advantage from mere perviousness of soil if it is so situated that its soil-water cannot get away. This very obvious consideration finds no expression on the foregoing tabular statements. In group A, for instance, the chalk is almost all high, while in group D low plains of gravel-covered chalk are reckoned under pervious soils, which might, as far as their water-holding faculty goes, as fitly find a place among the retentive formations.

Summary view by comparison of districts more or less resembling each other in geology.

But, leaving the method of grouping, and passing to the examination (B.) of more naturally comparable districts, the prevalence (α) *of phthisis upon pervious soils from which water can drain away, as compared with its prevalence upon retentive soils*, may first be investigated. The Wealden area of the south-eastern counties offers an excellent set of districts for the purpose of such a comparison—districts which differ from each other, too, in very few respects save in the matter of soil. The area in question comprises the Weald Clay, and the Hastings Beds of alternate sands and clays (page 61). Very different facilities of getting rid of water are presented by the elevated sands of the Hastings series and the flat plain of the Weald Clay; and, although there are no districts wholly of sand to contrast with others wholly of clay, the different effect of these soils respectively upon phthisis may be judged of by the different prevalence of the disease in districts formed by sands and clays in different proportions. Taking those districts where the majority of the people live in the Wealden area, and arranging them in the order of their consumptive mortality, the table on p. 104 shows the per-centage of people living on sandy soil and clay in each. Gravels over Weald Clay, being of intermediate importance, have been divided (in making the last columns) as if they were half sand and half clay.

Here the districts with less phthisis are seen to have more of their population on sands and less on clays, and those with more phthisis to have more population on clays and less on sands; the descending series of the per-centage numbers on sands and the ascending series of those on clays being wonderfully nearly regular for the districts arranged in the order of their consumption; so much is this the case, indeed, that they could not be expected to be more regular unless one should go the length of contending that phthisis was a disease influenced by no other circumstance than the one condition of soil.*

* It must be observed that the sands and clays of the Wealden area do not furnish the most thorough contrast that is possible in regard of water-retention, inasmuch as the sands are very fine and often clayey, and thus hold in water more than coarser sands or gravels. The displacement of Hambledon and Maidstone possibly may indicate that people living on Hythe Beds of the Lower Greensand are even better off, as regards consumption, than those on Hastings Sands; or else that the good qualities of gravels over Weald Clay have been under-estimated.

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DISTRICTS the Majority of whose Population live on the Weald Country.

Order of District among the Fifty-eight Districts, in order of Phthisis Mortality.	Per-centage of Population resident on						Total on	
	Higher Beds, mostly Lower Greensand.		Weald Clay.		Hastings Beds.		Sands and Half Gravels over Weald Clay.	Clays and Half Gravel on Weald Clay.
	Sands of.	Clays of.	With Gravel.	Without.	Sands of.	Clays of.		
2.? Hastings	—	—	—	—	95	5	95	5
15. Cranbrook	—	—	1	6	82	9	82	18
22. East Grinstead	—	—	—	12	82	6	82	18
23.? Tunbridge	—	1	24	7	64	4	76	24
25. Uckfield	—	—	—	1	87	17	87	17
28. Hambledon	49	—	20	31	—	—	59	41
29. Battle	—	—	—	—	80	20	80	20
40. Rye	—	4	—	—	79	17	79	21
42. Maidstone	43	1	45	11	—	—	66	24
43. Cuckfield	21	1	—	25	48	5	69	31
46. Hailsham	—	—	—	34	61	4	61	38
47. Ticehurst	—	—	—	—	67	33	67	33
51. Tenterden	—	—	—	29	42	29	42	58
53. Horsham	—	—	—	56	44	—	44	56
56. Petworth	30	—	—	70	—	—	30	70

Comparison of various districts of pervious soils, as to elevation.

In the second place (β), it is evident that *within the limits of "pervious soils"* may be included very great range of wet and dry soils, according to *the elevation of the ground and the dip of subjacent impervious beds;* and this consideration appears to affect notably the prevalence of phthisis. Thus the "gravels over London Clay" form throughout the north of Surrey, tracts of somewhat elevated or inclined ground, beneath which the impervious clay has a notable slope, usually towards a stream. Districts in which a considerable part of the population live on such gravels are Epsom, Chertsey, Croydon, Hoo, Richmond, Kingston (with 11, 29, 35, 65, 94, and 79 per cent. respectively of the population of each upon these gravels), and these districts stand respectively 4th, 12th, 13th, 14th (?), 16th, 17th, among the 58 districts in the order of their mean phthisis rates (Table, pages 59–60). But at the southern part of Sussex the London Clay forms almost flat plains scarcely above high-water mark, and water is necessarily much held up in the gravels over such clay. Westhamptnett and Chichester are the only two districts in which much of the population (viz. 29 and 69 per cent. respectively) live on such low lying gravel over London Clay, and these two districts are 53rd and 58th on the list of the 58 districts, Chichester being in the worst position of all.

A like distribution of phthisis is observed in the several districts where much of the population lives upon the Lower London Tertiary formation. On the north of Kent and Surrey such districts are more or less high lying, and their beds are chiefly of sands and pebbles. Several of these districts have such small phthisis rates that they stand quite at the top of the list, Dartford, Epsom, Milton, and Bromley being respectively 3rd, 4th, 5th, and 10th among the 58 districts. Other Lower London Tertiary districts follow at no great distance down the list. Eastry and Faversham, with good part of their population on this formation, stand no higher than 38th and 39th on the list, although the beds are mostly pervious; but the Lower London Beds here do not, for

reasons of elevation and dip, readily get rid of their water. There are other districts into which the same formation enters that are among the worst of the districts for phthisis, but here (Westhamptnett 53rd, and Westbourne 57) the beds are low, flat, and waterlogged, and themselves are less pervious than in the northern tract of the Lower London Beds.

The Chalk affords another illustration. No soil is drier than chalk when it has a fair elevation; it is so dry, indeed, that at its higher parts there are no streams, water cannot be reached by ordinary wells, and the people seek less elevated ground to supply themselves with the necessary element of water. In many districts the bulk of the population who live on Chalk occupy valleys with the water-line in the chalk not many feet below their houses; and in the south of Sussex a still greater degree of wetness is reached, for large part of the area reckoned as Chalk is a flat plain on the sea level, covered by gravel, with the dip of the Chalk here and there inland. If, with this preface, reference be made to the description of various districts which have a majority of their population on Chalk, and to the table on pp. 59–60, it will be seen that the position, as regards consumption, of those districts will on the whole represent the order in which they would stand if they were arranged according to the better or worse elevation of the chalk area on which the population live. Thus, North Aylesford, Thanet, and Dover, which stand together seventh, eighth, and ninth among the 58 districts, have their inhabited chalk areas far more elevated, and their water better carried off than Worthing, Lewes, and Westbourne, which are respectively 48th, 50th, and 57th on the list. And if the intermediate chalk districts be compared, then it is still found that they range themselves in much the same order in regard of consumption and in regard of the high or low situation in which their population lives. It is indeed difficult to say with exactness, in the absence of more minute local details, what the precise degree of dryness of a chalk district is, and still less certainly can this be stated for particular spots where masses of population come together; but the general connexion between small consumption and elevation of the chalk area is not to be mistaken, the only prominent exception being in the case of Brighton, about the true place of which in the series there is confessedly no accurate information.

Again, another illustration of the effect of elevation of porous soils may be found in a comparison of the several districts where the population live mainly upon Lower Greensand. Constructing for this formation a somewhat similar table to that relating to the Weald, and taking the per-centage of population living on pervious and retentive soils, we get a series agreeing with that of the Wealden table in showing generally a larger proportion of inhabited retentive soil, where the people suffer a greater consumption mortality. But there will be found on this table (besides the formerly observed irregularity of Hambledon, page 103, and note), a notable misplacement of Thakeham, in the series of figures that indicate the per-centage on pervious and impervious soil respectively. Now, the whole southern tract of Lower Greensand on which Midhurst and Thakeham are situated lies low, forming quite a different ground from the hills of the same formation on the north; but incomparably the worst district for wetness of soil is Thakeham, where most of the Lower Greensand Beds are pervious, but where they form a low flat plain, through which runs a stream bordered by broad flats of alluvium.

The only suggestion of an exception to the rule that flat low-lying sands and gravels have a larger amount of consumption than those whose elevation and slope allow of water being got rid of, is in the case of those districts which have a good many houses built upon shingle. Dover is one of these, a quarter of the district population living in the lower

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DISTRICTS where half or more of the Population live on Lower Greensand.

	Per-centage of Population resident on				Total on	
	Lower Greensand.		Other Formations.*			
	Pervious Beds.	Impervious Beds.	Pervious.	Impervious.	Pervious.	Impervious.
7. Godstone - -	59	—	28	13	87	13
18. Elham - - -	61	4	15	20	76	24
24. Reigate - - -	48	5	25	22	73	27
28. Hambledon - -	49	—	10	41	59	41
32. Malling - -	62	—	18	20	80	20
35. Sevenoaks - -	47	—	13	40	60	40
44. Dorking - -	56	—	12	32	68	32
49. West Ashford -	30	20	11	39	41	59
54. Midhurst - -	25	28	17	30	42	58
55. Thakeham - -	45	14	16	25	61	39

* Weald Clay, covered by gravel, being equally divided between these two columns, as in former tables.

parts of Dover town, in such houses. Dover district stands no lower than ninth in the list of the 58 districts, and Dover town, even before its sanitary improvements, had a very small death-rate from consumption. Now, though much of the town and all the rest of the district is upon chalk and rubble, well placed as regards dryness, it appears certain that neither the district nor the town would have a good character for consumption if the saturation of the shingle was of material evil influence.—Again, the district of Romney Marsh is as low lying and as wet as any of the 58 districts, but its place on the list is probably not farther down than 31. Half of Romney population live on shingle, the other half on a sort of estuary alluvium.—Eastry is the third district that has any considerable part of its population on shingle, notably the town of Deal. This district stands 38th in the order of its phthisis, below Romney Marsh, but then there are in Eastry other low-lying places not on the sea face, which would be expected to resemble in their phthisis rates some of the low-lying chalk and tertiary districts that have been shown to suffer considerably from the disease. Upon the whole, then, it appears probable that low pervious beds saturated by sea water have not so high a death-rate from consumption as those saturated by other water.*

Comparison between various districts of impervous soils.

Next (γ), *as to the impervious formations* that have been investigated in the three counties. The various clays of the Hastings series and the Sandgate Beds have had their influence sufficiently demonstrated in the two tables that have dealt with the distribution of phthisis in the Wealden and in the Lower Greensand districts respectively. Of the clayey Bracklesham Beds of the Bagshot Sands little has to be said, except that they are most represented in the district of Westhamptnett, which in its phthisis rate stands far below any other of the Bagshot Sand districts.

* At first sight indeed it does appear from the experience of Dover that getting rid of the subsoil water from the shingle has operated to reduce consumption, and it would therefore seem that the sea water had its degree of deleterious influence on the disease. But the drainage operations of Dover had certainly far more effect in removing spring water from the subsoil than in altering the saturation of the shingle by the sea. (9th report of Med. Off. p. 132.)

There remain the two widely distributed impervious formations, London Clay and Weald Clay, and some consideration must also be given to the alluvial deposit of river sides and estuaries.

London Clay and Weald Clay differ very importantly from each other (pp. 62–64), in three chief respects—(1.) London Clay in its main extent through the three counties forms long slopes and notable hills; Weald Clay forms sometimes gently undulating but for the most part flat level ground. (2.) London Clay over large tracts is covered by beds of gravel reaching to many feet in thickness; Weald Clay has only very local gravels disposed in undulations of the clay, and rarely at all thick. (3.) Weald Clay is always bounded immediately to the north and south by higher ground, so that other beds drain more or less into its area; London Clay forms a more open country, and the direction of drainage from other beds is generally away from it. All these considerations show that the London Clay has commonly a much less degree of wetness than the Weald Clay.*

The difference between the two formations in respect of their phthisis mortality is unmistakeable. Firstly when it is covered by gravel, London Clay stands, as has been shown, among the best of the formations, except when its low lying flat position in Sussex brings it into physical conditions closely comparable with the habitual condition of Weald Clay. Of Weald Clay when covered by its local gravels it can only be said that it has not, so far as can be judged, so extremely high a death-rate from phthisis among the residents on it as where it has no gravel.

Comparison of the two formations when uncovered by any gravel brings out their difference in respect of phthisis quite as positively. On reference to the descriptions of the districts and to the table, it does appear that much uncovered London Clay in a district places certain localities (*e.g.* Croydon No. 13, Kingston No. 18, Blean No. 19), in a worse position than others, where this clay is covered by gravels or the soil is otherwise pervious, and this happens even though the ground should not be (as it is at Westbourne) low and flat. But on the whole it appears that there may be in a district a notable proportion of uncovered London Clay, forming high and sloping ground (as in the case of Epsom and the districts just quoted), without that district experiencing a very serious consumption death-rate. But of the Weald Clay, the evil effect upon phthisis was already conspicuous upon the first table that showed the connexion between consumption and soil in the 58 districts (page 102); and the next table, in which the Wealden area was particularly examined (page 104), brought out the relation between this formation and phthisis into even stronger relief. Of districts that have a third of their population on ungravelled Weald Clay, the best in regard of phthisis stands no higher than 42nd on the list. Only London Clay, when exceptionally placed in the same fashion as Weald Clay, or flat plains of gravel lying on the sea level and saturated with wet, make their appearance along with Weald Clay districts in the last-named 10 places on the general list where the consumption death-rate is most excessive.†

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* Weald means Wood, and this country used to furnish much timber to Portsmouth dockyard. It is on record that after a wet season the transit of timber from Kent to Hampshire has taken two years to effect, owing to the impassable character of the roads through the Weald.

† The observation may now be added that of such districts as stand high on the phthisis list having 10 per cent. or so of their inhabitants on Weald Clay, many are models of dry soils in their other parts, and from that circumstance might now be expected to rank somewhat higher than they can rank with the inclusion of Weald Clay.

Apparent exception in case of alluvium.

As regards alluvium, it bears in most districts but a small proportion to the whole area, and the residents on it bears a still smaller proportion to the entire population of each. Moreover, the presence of alluvium generally indicates that some other parts of the district lie flat and low. Hence it is difficult to assign a value to this retentive formation in respect of its influence on phthisis. There are two districts, however, Sheppey and Romney Marsh, in the one of which half, and in the other more than half the people live on low flat clayey alluvial plains, the other half of the population of Romney living on shingle. Both these districts exhibit death-rates from phthisis different from what the general conclusions of this report would have led us to expect. They are both indeed districts of which the true death-rates can scarcely be affirmed and the precise place of which in relation to other districts is doubtful, but there is no doubt that Romney Marsh is not far below the middle and that Sheppey is somewhere near the head of the list in the order of the 58 districts, whereas other districts that form low wet plains are together at the bottom of the list, or are met with in a better position only as higher and dryer ground enters into their composition. The exceptional behaviour of these two districts in regard of their phthisis must either have some exceptional reason or it must be confessed that they seriously disturb the chief conclusions that have appeared to be gained. Now, in two respects these districts of Sheppey and Romney Marsh actually are different from other low flat places in the three counties, and in either of these respects an explanation may be sought of their exceptional immunity (absolute or comparative) from phthisis. Firstly, the suggestion may be made these two are the very districts where there is the most ague, and the old belief in the exclusion of phthisis by ague may be a truth. To this, however, it must be answered—(1) that proof of the belief has not been satisfactorily given, by the exclusion on one side and on the other of other conditions influencing the occurrence of each disease, and that much evidence has been brought forward in support of the contrary opinion; (2) that in some of the other districts examined there has been a good deal of ague, not as much as in Sheppey or Romney, but still a good deal, and certainly as late as 1859. But these districts, Faversham, Rye, Maidstone, and Lewes,* stand indifferently or badly among other districts in the amount of their consumption, being respectively 39, 40, 42, and 50 among the 58. (3) That at Sheerness, the principal town of Sheppey, built wholly on alluvium below high-water mark, there is not so much ague as in the higher lying parts of the district, Eastchurch and Minster, and there is also (on the testimony of Dr. Swales, of Sheerness) distinctly less consumption produced in the town than in the villages of Sheppey beyond Sheerness. Probably, then, the suggestion that phthisis is comparatively little prevalent in Sheppey and Romney, on account of the agues there, may be put aside with the remark that these districts furnish excellent examples of the sort of places concerning which the statements has been made. But another suggestion may be hazarded in favour of which is the analogy of the towns upon shingle already discussed. In the same way as towns built on low lying pervious soil stand exceptionally well in their amount of phthisis if their soil be

* Milton and Hoo (so far as any inference can be drawn from the small population of Hoo) are other districts which have intermittents, and yet go along with Sheppey and Romney in not having very much phthisis. Both, however, range themselves pretty intelligibly when classified by their geological characters. But yet they may require some such consideration as is being advanced for Sheppey and Romney to account for their being better than some other districts in regard of their consumption rate.

saturated by sea water, so may not places situated like Sheerness and Romney, on sites which are scarcely more of land than sea, have an exceptional immunity from phthisis among those districts that have flat retentive soils? No other of the south-eastern districts at all resembles these two in the degree to which their soil has been gained and is (more or less artificially) withheld from the sea.* Without venturing to give an answer to this question, it may be allowed that there is enough of special character in the conditions of Sheppey and Romney districts to separate them from the numerous low-lying districts, upon the uniform experience of which it is stated that low-lying retentive soils have high mortality from phthisis.

The following general conclusions then result from the present inquiry:—

Summary of conclusions.

(1.) Within the counties of Surrey, Kent and Sussex there is, broadly speaking, less phthisis among populations living on pervious soils than among populations living on impervious soils.

(2.) Within the same counties, there is less phthisis among populations living on high-lying pervious soils than among populations living on low-lying pervious soils.

(3.) Within the same counties, there is less phthisis among populations living on sloping impervious soils than among populations living on flat impervious soils.

(4.) The connexion between soil and phthisis has been established in this inquiry—

(*a*) by the existence of general agreement in phthisis mortality between districts that have common geological and topographical features, of a nature to affect the water-holding quality of the soil;

(*b*) by the existence of general disagreement between districts that are differently circumstanced in regard of such features; and

(*c*) by the discovery of pretty regular concomitancy in the fluctuation of the two conditions, from much phthisis with much wetness of soil to little phthisis with little wetness of soil.

But the connexion between wet soil and phthisis came out last year in another way, which must here be recalled—

(*d*) by the observation that phthisis had been greatly reduced in towns where the water of the soil had been artificially removed, and that it had not been reduced in other towns where the soil had not been dried.

(5.) The whole of the foregoing conclusions combine into one—which may now be affirmed generally, and not only of particular districts—that WETNESS OF SOIL IS A CAUSE OF PHTHISIS TO THE POPULATION LIVING UPON IT.

(6.) No other circumstance can be detected, after careful consideration of the materials accumulated during this year, that coincides on any large scale with the greater or less prevalence of phthisis, except the one condition of soil.

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* Even the towns of Rye district on the borders of Romney Marsh are on a rise that takes them comparatively away from the sea. Sea-atmosphere alone does not appear to influence the prevalence of phthisis; the districts at the south of Sussex that have been repeatedly cited as the worst in their phthisis rates are mostly on the coast, and, on the other hand, Hastings and Thanet, which stand extremely well, are on the coast likewise. It is possible that in the suggestion of the text there may be a clue to the cause of the discrepant evidence about phthisis and ague? Does a salt water marsh give to those who live on it a disposition to ague but not to phthisis? while a river marsh or flat soil in proximity to a salt marsh conduce to both ague and phthisis?

(7.) In this year's inquiry, and in last year's also, single apparent exceptions to the general law have been detected. They are probably not altogether errors of fact or observation, but are indications of some other law in the background that we are not yet able to announce.

POSTSCRIPT.—The conclusions of this report had been drawn, and their agreement with observations of last year's report had been seen, when, at the end of 1867, my attention was directed by Dr. Gavin Milroy to the Seventh Annual Report of the Registrar-General for Scotland, in which (pp.xlvii–xlviii), he quotes "the conclusions which Dr. Bowditch " of Boston, U. S., has drawn from a very thorough inquiry into one " of the causes of consumption in Massachusetts." The Registrar General writes: "It must be remembered that consumption is much " more fatal in Massachusetts, and in the United States of America " generally, than in this country; and on investigation it was found " that the towns, villages, hamlets, and houses which were situated at " or near undrained localities, or were on heavy impermeable soils, or " on low lying ground, and whose sites were consequently kept damp, " had a very much larger number and proportion of cases of con- " sumption than towns, villages, hamlets, or houses which were situated " on dry or rocky ground, or on light porous soils where the redundant " moisture easily escaped. Let us see how such an explanation would " agree with the very different proportion of deaths from consumption " which occur in the eight principal towns of Scotland. Taking a five " years' average (1857 to 1861 inclusive), it is found that, supposing all " these towns are brought to an uniform population of 100,000 persons, " there died annually from consumption 206 persons in Leith, 298 in " Edinburgh, 310 in Perth, 332 in Aberdeen, 340 in Dundee, 383 in " Paisley, 399 in Glasgow, and 400 in Greenock. The fact is, that if " each town had been arranged in the order of comparative dryness of " its site, they would almost have arranged themselves in the above " position—Leith and Edinburgh the most free from consumption, and " also having the driest sites; Glasgow and Greenock the most ravaged " by that disease, and beyond all comparison situated on the dampest " sites. The above fact, then, with regard to the towns, corroborates, " in the most striking manner, the conclusions of Dr. Bowditch, and " should be a valuable help to the sanitary reformers, as to the very " important measures which it is their more especial province to carry " out. Dr. Bowditch's conclusions also are singularly borne out by the " remarkable freedom from consumption at the Cape of Good Hope and " South Africa generally, Egypt, etc., and the comparatively high mor- " tality from it in the moist climate of Great Britain; and while they " point out the cause, afford valuable indications as to the cure or relief " of those affected."

Until the end of my own inquiry, I was in complete ignorance of Dr. Bowditch's researches. I should not insist on this point, except for the purpose of giving to the conclusions which Dr. Bowditch and myself have obtained the additional weight that they deserve from having been arrived at by a second inquirer, wholly ignorant of and therefore unbiassed by the work of the first. Several efforts that I have made to obtain a copy of Dr. Bowditch's pamphlet have unfortunately failed, and I am therefore unable to give, as I had wished, an abstract of the observations which he brings to the support of his conclusion.

No. 6.—DR. SANDERSON'S REPORT on the COMMUNICABILITY of TUBERCLE by INOCULATION.

The investigations to which the following report relates, were undertaken in co-operation with the Medical Officer of the Privy Council for the purpose of testing the truth of certain statements recently made on high scientific authority, as to the effects of inoculating animals with morbid products derived from persons affected with tubercular disease, and of determining to what extent, and under what conditions, this or other allied diseases of man can be transmitted to the lower animals.

Scope of the inquiry.

The problems which appear to me to be comprised within the scope of such an inquiry may be stated as follows:—

1. Is it true that the inoculation of tuberculous matter produces in the lower animals morbid changes, so constant in their anatomical character and development that they may be regarded as constituting a disease? And if so, in what terms can it be defined?

2. In what respects do the morbid results produced by the inoculation of tubercle resemble or differ from other diseased conditions communicable by the same process, particularly pyæmia, glanders, and syphilis: and to what extent are they comparable with the effects produced by the introduction into the circulation of inert solid matter in a state of fine division?

PART I. INOCULATION OF TUBERCULOUS MATTER.

For the determination of the first question, experiments have been made on 53 guinea-pigs. Of these, 30 were inoculated directly with diseased material from tuberculous patients, and 23 with material taken from the diseased organs, or with the blood, of animals previously inoculated. Of the latter, 13 were inoculated directly from animals of the first series, which in their turn yielded material for the inoculation of the remainder. Of these animals some are still under observation, but a sufficient number have died of the effects of inoculation, or have been killed for anatomical purposes, to enable me to report fully on the structural characters and development of the lesions produced. The quantity of material used in each inoculation was extremely small. The mode of insertion employed will be described below.

Primary inoculations.

FIRST SERIES. INOCULATION OF HUMAN TUBERCLE.

Observation I. Inoculation of grey granulations of pia mater.

OBS. I., April 16th.—Three guinea-pigs were inoculated with tuberculous material from the pia mater of a patient who had died three days before in the hospital for sick children, under the care of Dr. West. The patient, a boy aged four years and seven months, had been admitted six days before his death with symptoms of tubercular meningitis, the disease having already existed three weeks. His health had been good until two months previously, when he had an attack of scarlatina, from which, however, he recovered, and remained well until the 25th of March, when a succession of convulsive seizures occurred, ushering in his fatal illness. The following were the results of the post-mortem examination:—On removing the calvarium and dura mater the convex surface of the hemispheres was seen to be moist, and the convolutions were flattened. The intervals between them, especially round the branches of the middle meningeal artery, were beset with granular deposit, which, however, was strictly limited to the sulci. The sectional surfaces of the brain were moist and pale, and the ventricles were distended with serum. The surfaces of the corpora striata

were roughened with minute granulations, and the septum lucidum was ruptured. On examining the base of the brain the pia mater covering the interpeduncular space was seen to be much thickened and hyperæmic. The thickening extended into the sylvian fissures, both of which were blocked up by exudation, and on opening up the right fissure, a mass of tuberculous matter as large as a filbert was exposed. All the other organs were carefully examined, but no trace of tubercle could be discovered.

Microscopical dissection.—On making sections of the mass of the right sylvian fissure it was found to be partly grey and semi-transparent, partly white and opaque. The grey parts consist of a transparent matrix, in which innumerable round or oval nucleated cells and nuclei are embedded. The diameter of each cell scarcely exceeds that of its nucleus. In some parts of the structure the nuclei, instead of being round or oval, present all intermediate forms between the spheroidal and those usually found in the connective tissue of the pia mater. The opaque white parts appear to consist of granular stroma, in which nuclei are still to be observed in greater or less abundance. Similar appearances present themselves in the thickened pia mater at the base of the brain. Not only here, but on the surfaces of the corpora striata, the vessels of the affected parts exhibited the usual changes. The multiplication of nuclei or nuclear cells had taken place in the sheaths of many of the capillary arteries to such an extent as to conceal their natural structure.

The three animals were inoculated from the tuberculous mass above described. The method employed consisted in passing a narrow-bladed scalpel under the skin, and then inserting the material into the wound with a pair of fine-pointed forceps.

No. 1. The animal was killed 56 days after inoculation. Morbid appearances were observed at the seat of insertion, in the lymphatic glands, in the spleen, liver, and lungs. The spleen was employed to inoculate three other animals. (See Obs. XI.)

No. 2. Killed 70 days after inoculation. The same organs were diseased. Three healthy animals were inoculated with morbid matter from the spleen, and three others with the blood. (See Obs. XII. and XIII.)

No. 3. Killed 93 days after inoculation. The lungs were healthy, the liver was scarcely at all diseased, but the spleen and lymphatic glands, as well as the subcutaneous cellular tissue at the seat of inoculation, exhibited the same appearances as in the other two animals.

Observation II. Inoculation with sputum of a patient affected with phthisis in the third stage.

OBS. II., May 2nd.—Four guinea-pigs were inoculated with sputum, collected three hours previously, of a patient affected with phthisis in the third stage, under the care of Dr. Quain, at Brompton Hospital. The patient died on the 16th of June, when the following appearances were noticed:—There were extensive and firm adhesions of both pleuræ. The right lung was for the most part crepitant, but beset with grey granulations, the smallest of which were semi-translucent. There was a small cavity near the apex, the base of the lung being hyperæmic and airless. The left lung was much contracted, of fibro-cartilaginous consistence, and perfectly airless. At its upper part was a large cavity containing much grumous fluid, and smaller cavities were scattered here and there throughout its substance. The pericardium was adherent by both its surfaces, and was much thickened. When stripped off the heart it left a surface roughened with shaggy lymph. With the exception of ulceration of the ileocæcal valve there were no important lesions of other organs.

The material used for inoculation was purulent and creamy sputum, here and there streaked with blood. It was found on microscopic examination to consist of pus cells, ropy mucus containing albuminous granules and oil globules, shreds of lung tissue, and sporules of fungi.

The animals were inoculated with an instrument devised for the purpose. It was similar to that subsequently used (see Obs. III.) but less perfect.

No. 4. Died 54 days after inoculation. The lymphatic glands, lungs, liver, and spleen were diseased. The condition of the subcutaneous cellular tissue was not noted either in this or the following case.

No. 5. Died 51 days after inoculation. All of the internal organs were diseased.

No. 6. Died 75 days after inoculation. The usual appearances were observed at the seat of insertion, in the lymphatic glands, and in the internal organs.

No. 7. Killed 77 days after inoculation. There were no morbid appearances.

Observation III. Inoculation of sputum of a patient affected with phthisis in the third stage.

OBS. III., May 10th.—Two guinea-pigs were inoculated with recent expectoration of a female patient, admitted into Brompton Hospital on the 9th of March, under the care of Dr. Quain. Death occurred on the 13th of May. The record of the post-mortem examination (at which I was present) was unfortunately not entered in the hospital register. At the time that the expectoration was collected the patient was in a state of extreme prostration, accompanied with the usual symptoms of the final stage of phthisis. The physical signs afforded evidence of extensive disintegration of the upper parts of both lungs, and of the existence of one or more large cavities at the apex of the left lung. This diagnosis was verified after death.

The sputum consisted of pus corpuscles similar in character to those above described. It contained fatty and albuminous granules, and various forms of fungus growth, viz., hyphaceous filaments, and spores of two varieties, one of which exhibited a necklace-like arrangement.

The instrument used for these and all subsequent inoculations consists of a steel canula, about three-fifths of a line in diameter, pointed at one end like the tube of a subcutaneous injection syringe, and fitted with a steel rod, which is of the same length and bevelled in the same manner as the canula. In using it, the material to be inoculated, if liquid, is drawn into the pointed end of the tube by pulling back the rod or piston for a line or two. If it is intended to employ solid matter, the instrument is easily charged by introducing the material into the same part of the tube with the aid of a pair of fine forceps. In inoculating, the point is passed under the skin to such a distance as to cover the whole of the bevelled part in the same manner as in hypodermic injection, and the material pushed out with the rod. In this way the insertion is accomplished with the utmost certainty, and with the least possible injury to the subcutaneous cellular tissue.

No. 8. Killed 69 days after inoculation. There was suppuration in the course of the wound, enlargement and softening of the subcutaneous lymphatic glands, and advanced disease of the spleen, liver, and lungs.

No. 9. Died 78 days after inoculation. The morbid appearances were similar to the last.

Observation IV. Inoculation of caseous

OBS. IV., May 14th.—Two guinea pigs were inoculated with caseous material from the lung of the patient whose sputum was employed in Obs. III., who died two days previously.

No. 10. Died 45 days after inoculation. Disease existed at the seat of inoculation, in the spleen, liver, and lungs.

No. 11. Killed 65 days after inoculation. The morbid appearances were of the same nature, but the lesions found in the internal organs were more advanced.

material from the lungs of the same patient.

Observation V. Inoculations of miliary tubercle of lung.

OBS. V., May 28th.—Two guinea-pigs were inoculated, one (No. 12) with miliary tubercle from the lung, the other (No. 13) with miliary granulations from the peritonæum of a patient who died of acute tuberculosis in Middlesex Hospital, under the care of Dr. Goodfellow. The morbid appearances were as follows :—Both pleuræ were studded with minute semi-transparent granulations, the right being partially adherent. Grey miliary granulations were disseminated abundantly throughout both lungs, especially the left, but *no deposits of old tubercle could be discovered.* The under surface of the diaphragm and the serous coverings of the liver and spleen were dotted with granulations, those on the liver having membranous shreds attached to them. The liver substance appeared normal to the naked eye, but on microscopic examination "numerous minute aggregations of nuclei, having all the characters of tubercle," (Dr. Cayley), were found to be disseminated through it. Several opaque yellow nodules existed in the kidneys, the size of which varied from that of a millet seed to that of a hemp seed. There were small tubercular ulcers in the ileum, particularly in Peyer's patches, and the corresponding mesenteric glands were enlarged. The pia mater was injected and ædematous, and grey granulations were observed in the sylvian fissures. No other morbid appearances were detected.

No. 12. Died 31 days after inoculation. There was disease of the spleen, lungs, and liver. The lymphatic glands were also diseased, but the state of the wound was not noted.

No. 13. Died 45 days after inoculation. There was suppuration in the course of the wound, with enlargement and softening of the lymphatic glands; the internal organs exhibited the usual appearances.

Observation VI. Inoculation of caseous material from the lung of a patient affected with phthisis.

OBS. VI., May 28th.—Three small guinea-pigs were inoculated with infiltrated tubercle (caseous pneumonia) from the right lung of a female patient, aged 22, who died in Brompton Hospital the day before, under the care of Dr. Pollock. The condition of the diseased organs was as follows :—There were firm adhesions of the right pleura towards the apex, the rest of the pleural cavity containing coagulated blood, the origin of which was not ascertained. The right lung, with the exception of the posterior part of the lower lobe was densely infiltrated with solid tuberculous material. Near the apex there was a small cavity containing grumous fluid. The left pleura, which was slightly adherent, and the left lung was free from tubercle excepting at its apex, where there were a few small masses of consolidation. The other organs were healthy.

No. 14. Died 44 days after inoculation.

No. 15. Killed 54 days after inoculation.

No. 16. Killed 54 days after inoculation.

In all these animals the lymphatic glands, spleen, lungs, and liver were diseased. In No. 16 there were also nodular deposits in one of the kidneys. The inoculation wounds and the surrounding subcutaneous cellular tissue exhibited the usual appearances.

Observation VII. Inoculation of infiltrated tubercle of

OBS. VII., May 28th.—A guinea-pig was inoculated with material from marginal infiltration surrounding an intestinal ulcer in a female patient, aged 43, who died the day before in Brompton Hospital, under the care of Dr. Alison. The condition of the organs was as follows :—

The upper two-thirds of the left lung were infiltrated with grey deposit, the lower third containing air. The right pleura was firmly adherent, and the right lung was scattered with tuberculous masses. There were numerous ulcers of irregular form with thickened margins in the cæcum and ascending colon; rounded ulcers of similar character were met with at intervals towards the lower end of the ileum, some of which were as large as a florin. The other organs presented no lesions of importance.

No. 17. Killed 54 days after inoculation. The pathological appearances observed at the seat of inoculation, in the lymphatic glands, and in the internal organs were of the same kind as in the other experiments.

mucous membrane of ileum.

Observation VIII. Inoculation with miliary tubercle of lung.

OBS. VIII., May 31st.—Three guinea-pigs were inoculated with miliary tubercle from the lung of a female patient, aged 27, who died at the Brompton Hospital three days previously, under the care of Dr. Pollock, of acute tuberculosis complicated with cerebral symptoms. Both lungs were scattered with miliary nodules of grey semi-transparent material; the pleura was in some parts natural, in others more or less opaque as if infiltrated with opalescent deposit, while in others it was studded with numerous granulations, some of which were exceedingly minute, others as large as hemp seeds. These on microscopic examination were found to consist of nuclei of various forms and sizes, which appeared to be grouped in greatest abundance in the neighbourhood of minute arteries. The pia mater exhibited no appearances of disease which could be recognised by the naked eye, but on microscopic examination it was found that there was multiplication of nuclei in the sheaths of the capillary arteries.

No. 18. Died 98 days after inoculation.
No. 19. Died 28 days after inoculation.
No. 20. Died 56 days after inoculation.

In each case the lymphatic glands, liver, and spleen were diseased; the lungs were diseased in No. 18, but were free from disease in Nos. 19 and 20.

Observation IX. Inoculation of infiltrated tubercle of great omentum.

OBS. IX. June 10th.—Two guinea-pigs were inoculated from tuberculous deposit in the great omentum of a patient who died in Brompton Hospital, under the care of Dr. Alison. In this case the most important post-mortem appearances were as follows:—Both pleuræ were firmly adherent; grey, elevated miliary granulations were disseminated throughout the whole of both lungs. The bronchial tubes were dilated and the bronchial mucous membrane thickened and injected. The bronchial glands were enlarged and indurated. The heart was firmly adherent to the pericardium, the aortic valve atheromatous and incompetent. The peritoneal cavity contained about two pints of greenish fluid. The mesentery was scattered with grey granulations. The omentum was thickened and indurated, and formed a hard mass, which during life had been felt through the abdominal wall. The spleen was enormously enlarged and hyperæmic, and contained masses of cheesy deposit. In the cortical substance of the kidney there were also several nodules of cheesy material. The mesenteric glands were much enlarged and indurated.

No. 21. Died 108 days after inoculation.

No. 22. Died 93 days after inoculation. With the exception that the morbid processes were more advanced in all the organs, the appearances corresponded with those previously observed.

SUMMARY of PATHOLOGICAL APPEARANCES observed in the above 22 Animals.

1. *Appearances observed in the wound produced by inoculation, and in the surrounding subcutaneous areolar tissue.*

Induration and suppuration in and around inoculation wound. Secondary subcutaneous abscesses.

In the animals first dissected my attention was not drawn to the importance of these appearances, so that the following statement is based on the dissection of nine animals only, viz., Nos. 3, 8, 11, 15, 16, 17, 18, 20, and 21. The morbid alterations observed consisted in (1) induration and thickening of the subcutaneous connective tissue; (2) formation of pus in the track of the wound; (3) formation of secondary subcutaneous abscesses in its neighbourhood; and (4) formation of bands of induration, analogous to farcy cords, between one abscess and others in its neighbourhood. In each of the nine animals referred to there was evidence that suppuration had taken place in the track of the wound; in all excepting one (No. 3) an abscess actually existed at the time of the dissection; in the exceptional case there was an open wound from which pus had escaped. The induration varied in extent; it was usually considerable, forming a hard ridge by which the course of the inoculating instrument could be traced before the skin was removed. In five of the animals numerous abscesses were found in the neighbourhood of the wound. In the four remaining, although there were no abscesses, there was much thickening and condensation of the subcutaneous tissue, which often proceeded to a considerable distance from the seat of the inoculation.

Minute anatomy of subcutaneous lesions.

Microscopical dissection.—The pus found in the primary traumatic abscess, as well as that which occupied the secondary abscesses in its neighbourhood varied in character according to the time that the abscess had existed; it never possessed either the fluidity or the characteristic yellow colour of normal human pus, its consistence varying from that of cream to that of cream cheese, which it also resembled in colour. Under the microscope it exhibited the following elements:—

In recently formed abscesses the majority of the corpuscles presented characters which do not appear to me to be distinguishable from those of normal human pus. These corpuscles measured from $\frac{1}{2500}$ to $\frac{1}{2000}$ of an inch in diameter, and exhibited when treated with very dilute acetic acid from two to four highly refractive granules, forming a central nucleus. Along with these were always observed other corpuscles of less uniformly spheroidal form, which resembled conglomerates, and usually contained a greater or less number of fat granules. These were much larger than the ordinary pus corpuscles, their diameter being from $\frac{1}{1200}$ to $\frac{1}{800}$ of an inch. In the older abscesses, that is those in which the pus had become cheesy, a marked difference was observed in the character of the corpuscles, and particularly in their conduct when acted upon by weak acetic acid. This reagent was found to have lost its power of resolving the corpuscles into a bifid, trifid, or quadrifid nucleus enclosed in a zone of transparent substance; in short, the corpuscle was comparatively little altered by the acid, and retained a distinctly globular form. The larger glomeruli were found in much greater numbers in the caseous than in the creamy abscesses, and in some instances appeared to be the only corpuscular elements. (Plate I., fig. 7.)

The structural character of the connective tissue indurations was observed (1) in the cords of induration, connecting one abscess with another, and (2) in the walls of the abscesses. The cords were found to consist of a dense fibrillated stroma, in which the direction of fibrillation was parallel to the axis of the cord. This stroma was not in the slightest degree wavy, and when fine sections of it were made

in the direction of fibrillation it was found to be studded with innumerable staff-shaped nuclei, all of which assumed the same direction as that of the fibrillation. On the most careful examination of transverse sections no trace could be discovered of any vessels larger than $\frac{1}{500}$ of an inch, so that it appears to me impossible to regard these cords as thickened lymphatics. It was further noticed that around the capillary arteries there were accumulations of nuclei which differed from the ordinary staff-shaped nuclei of the tissue in being fusiform or spheroidal. In addition to this there were nests of corpuscles which could not be distinguished from the pus corpuscles of the neighbouring abscesses. Is it possible that these were pus corpuscles in the act of migration, and that the growth of connective tissue which constitutes the cord is the result of the irritation produced by them in their passage?

In making sections of walls of abscesses it was found that they always presented the same structure, viz., that they invariably consisted of condensed connective tissue, having the same character as that which forms the cords of induration. This tissue was continuous, externally, with the normal subcutaneous tissue. Internally, the abscess wall was lined by a layer of pulpy substance. This material (so called pyogenic membrane) was found, when examined separately, to consist of spheroidal cells* embedded in the meshes of a reticulated transparent stroma; when examined in sections made perpendicularly to the abscess wall it could be satisfactorily made out that this stroma was continuous with that of the dense fibrillated connective tissue on which the pyogenic membrane rested. (Plate I., fig. 4.) Appearances seemed also to justify the conclusion that the crowded, round, corpuscles of the pyogenic pulp, were homologous with the staff-shaped nuclei of the denser layers which surround it, but I was not able to satisfy myself of the existence of transitional forms. Well characterized capillary blood vessels were seen in the fibrillated layer, and channels containing blood corpuscles could be distinguished at all events up to the edge of the pyogenic pulp. In the areolar tissue, and among the muscular fibres of the panniculus near the abscesses, nests of spheroidal or spindle-shaped corpuscles were everywhere met with.

2. *Appearances observed in the Subcutaneous Lymphatic Glands.*

Enlargement, induration, caseous degeneration, softening, and suppuration of the subcutaneous lymphatic glands.

In all the animals the subcutaneous lymphatic glands were more or less diseased, the changes consisting in enlargement (hyperplasia), induration, and caseous degeneration; this last resulting either in softening or in the formation of cretaceous concretions. In every instance those glands were most affected which were in the neighbourhood of the inoculation wound. As therefore the insertion was usually made in the shoulder, the axillary glands, as might be readily anticipated, were the principal seat of disease. So constantly indeed was this the case, that it could always be discovered whether an animal was diseased or not by pressing the finger in the axilla. In the healthy guinea-pig two glands can be distinguished in the axillary region as being much larger than the rest; one lies close to the axillary artery, where it crosses the shoulder joint; the other is situated near the posterior edge of the scapula in the angle between the triceps muscle and the teres maximus. The latter, which in the guinea-pig is more frequently diseased

* In employing the word "cells" I do not mean to imply a belief that the objects in question are vesicular.

than any other, will be hereafter referred to as the scapular gland. The other subcutaneous glands which are apt to be affected are those which lie on either side of the trachea (tracheal glands), and those near the sub-maxillary salivary glands (sub-maxillary glands). The inguinal glands are also occasionally diseased.

The enlargement of the glands was enormous. In the greater number of animals the scapular gland had attained 40 or 50 times its normal weight, and five or six times its natural length. Enlargement was never observed without other changes. The hypertrophied glands always exhibited in section, patches of white or yellowish opacity of the cortical substance, indicating the commencement of caseous degeneration. The condition of the glands, as of the subcutaneous areolar tissue, was carefully investigated in nine animals only. In three of these, Nos. 16, 17, and 20, there was hypertrophy, with induration and cheesy degeneration. In the six remaining animals the scapular gland on the same side as the inoculation wound was converted into an abscess containing creamy or cheesy pus, and in one of these animals, No. 21, the tracheal glands of the same side were in a similar condition. It was further observed, with reference to these nine guinea-pigs, that the three cases in which there was no suppuration of the glands, were precisely those in which there were no abscesses under the skin in the neigbourhood of the inoculation wound, so that there was reason to regard the softening of the lymphatic glands as dependent upon the same conditions as the dissemination of purulent foci in the subcutaneous tissue.* The structural characters of the lymphatic glands were not investigated microscopically, my attention having been directed principally to the internal lesions.

3. *Appearances observed in the Lungs.*

General nature of the lesions observed in the lungs.

Of the 21 guinea-pigs successfully inoculated the lungs were found free from disease in three only. In the rest the lesions observed consisted in the formation of nodules of grey induration, which were disseminated in 14 of the cases, partly disseminated, partly confluent in the rest. These changes were in two animals associated with adhesive pleurisy, viz., in Nos. 10 and 21.

Increase of weight.

In the healthy guinea-pig the lungs weigh about four grammes, that is about one-hundredth part of the weight of the body. When altered by adenoid deposits they often weigh as much as 15 grammes. In those cases in which the nodules are small and much disseminated the weight scarcely exceeds the normal. The increase of weight due to the new growth was most considerable in those in which the duration of life after inoculation was greatest; thus, in three animals which, when dissected, had been inoculated respectively 93, 98, and 108 days, the weights were severally 2·2 per cent., 3·7 per cent., and 4·9 per cent. of the weights of their bodies.

Disseminated nodules.

As has been stated, the new growth either assumed the form of disseminated nodules or pervaded the tissue of the lung to such an extent that considerable portions of the organ were consolidated. There was, however, evidently no essential difference between the two forms of lesion, for in those cases in which the induration was continuous in some parts, it was constantly observed that there were disseminated nodules in others, and that the material of which the nodules were composed was identical in all its characters with that which formed the larger masses. We

* This inference was confirmed by later experiments.

proceed to describe the nodular, which must be regarded as the primary form of the alteration.

The nodules, when examined with the naked eye or with a lens, present great uniformity of appearance. They are always found in much greater numbers under the pleura than in the parenchyma of the lung. The sub pleural surface of each nodule is slightly convex, so that it projects more or less above the general surface of the pleura, exhibiting itself as an iron-grey patch, which contrasts strongly with the pink white hue of the healthy lung tissue which surrounds it. When the nodules are small the whole sub-pleural surface is convex, but in the larger nodules the centre of the patch is somewhat depressed, so that the margin forms an irregular annular prominence. On cutting through a nodule at right angles to the pleural surface it often appears to form a blunt cone, of which that surface is the base. The colour of the nodules is sometimes pale grey, but much more frequently it is steel grey or slate coloured, especially towards its margin; and on section it exhibits a similar colour. The smaller nodules have the semi-transparent appearance which is recognized as a characteristic of miliary tubercle. In the larger ones the translucency is confined to the external parts, the centre being opaque, and of softer consistence than the rest. There are, as may readily be understood, great differences as regards size. In two of the animals they were all no larger than pin-heads, while in others the diameters varied from one-fiftieth to one-tenth of an inch. From their form and structural relations it is evident that they are interstitial new growths which do not displace the lung tissue, but are incorporated with it and form part of it. In order to satisfy one's self of this fact, all that is necessary is to examine those nodules which happen to lie near the sharp margins of the organ. It is then readily seen that the form which each nodule assumes is not its own, but that of the organ in which it grows, and that the space it occupies is often not greater than that which would have been occupied by the corresponding portion of lung in the natural state.

Form of the nodules.

Their colour, consistence, and semi-transparency.

Their size.

Their structural relations.

In most cases the nodules are very equally dispersed through the affected organs; exceptions occur in which one lobe is found to be more abundantly infiltrated with new material than the rest, but these appear to be accidental, all parts of the organ being apparently equally liable to become the seat of consolidation. In one of the animals I counted 63 separate sub-pleural nodules, which were disseminated with equal frequency over the whole of the surface of both lungs, while as regards several others it is noted that they were too numerous to be counted. Although, as has been already stated, the greater number are superficial, there are many which occupy central positions, and these, so far as I have been able to ascertain, are invariably found in the neighbourhood of bronchi. It was never observed that the deposits were surrounded by a zone of inflammation. Occasionally the lung tissue around their margins was slightly injected, but this appearance was neither constant nor definite; the adjoining lung tissue was in general perfectly healthy in structure and appearance. It has already been stated that, in those cases in which the whole of a lobe was converted into a mass of new deposit, the appearance and consistence of the material were evidently the same as of that which constituted the nodules, for often, as in No. 21, it could be distinctly seen that what resembled infiltration was produced by the mere grouping together of smaller masses; it must at the same time be admitted that the difference between the confluent and disseminated forms of lesion was not entirely one of degree, for sometimes it was noticed that the whole of one of the lobes was consolidated,

Their distribution.

Confluent induration.

APPENDIX.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

as in No. 14, although in other parts of the lung the amount of new material was inconsiderable.

In every case in which the nodules had attained a considerable size their centres were found to be softened. In one animal, No. 8, this softening had proceeded to such a degree that some of the masses were converted into vomicæ containing creamy fluid.

Formation of vomicæ.

Microscopical characters of new growths.—In the microscopical examination of the morbid growths above described it was found that very little progress could be made unless the parts to be examined were first hardened by steeping them for several weeks in a solution containing one-quarter per cent. of chromic acid. The anatomical statements contained in the following paragraphs are founded entirely on the examination of sections of diseased lungs prepared in this way.

Minute anatomy of nodular indurations.

Peribronchial granulations consisting of adenoid tissue.

The disease always originates in the form of minute granulations, each of which, so far as I have been able to ascertain, is situated around, or in the immediate neighbourhood of a minute bronchiole, usually a bronchiole of three or four thousandths of an inch in diameter. One of these granulations is represented in the margin as seen with a low power. On more minute examination it is found to consist in the main of adenoid tissue, that is tissue resembling the pulp* of the cortical substance of a lymphatic gland; in other words, it is composed of nuclei, most of which appear to be free, although many of them are enclosed in "cells" little larger than themselves. These elements are embedded in a sponge-like stroma of extreme delicacy, in which no fibres or vascular channels can be distinguished. (Plate I. fig. 5.)

Origin of the new growth in the alveolar tissue of the lung.

The mode of origin of this tissue can only be judged of after its relation to the original structures of the lung has been determined. According to the best anatomists the walls of the pulmonary air cells (*i.e.* the pulmonary parenchyma) consists of an homogeneous transparent substance supported by a framework of elastic fibres, which in its turn serves to support the delicate epithelium of the air cells, while it includes the capillary network. (See plate I., fig. 3.) The examination of diseased lungs in the earliest stage of alteration seems to show that this homogeneous transparent substance which constitutes, so to speak, the interstitial stroma by which the other structural elements of the lung tissue (elastic trabeculæ, capillaries, epithelium,) are combined and held together, so as to form the delicate vesicular parenchyma of the healthy lung, is itself the matrix in which the new growth originates. How this transparent material is converted into adenoid tissue is a question not yet determined; all that can be seen is that it becomes loculated and that each vesicle contains one or more round bodies, which we designate as nuclei. At first the new growth is confined to the immediate neighbourhood of the bronchioles, from which it extends to the walls of the adjoining air cells; here it gives rise to a general thickening of the alveolar membrane, and consequent reduction of the capacity of each alveolus, and consolidation of the affected part.

Thickening of the alveolar walls.

* This pulp consists of masses or nests of cells, identical in their character with those described in the text, which are held together by a delicate network of transparent material, wherein capillary blood channels are contained, and fibres of extreme tenuity can be detected.—See Kölliker. Handbuch der Gewebelehre Menschen, 1867. P. 474.

As the process goes on, the bronchioles leading into the affected air cells probably become more or less obstructed, but do not undergo any appreciable change of structure, for in bronchial tubes which are surrounded on all sides by adenoid growth (see Plate I., fig. 5.) it may happen that there is no alteration either in the epithelium or in the tube wall; there is not the slightest sign of any inflammatory process affecting the bronchial mucous membrane. Eventually the diseased part becomes completely consolidated. This is brought about partly by the interstitial growth of cells in the substance of the alveolar walls, partly by the accumulation of epithelium in the alveolar cavity.* Whether by compression of the ultimate bronchus, or for other reasons, the epithelium collects in the vesicles, already reduced in size by the parietal thickening, so as to fill them up. In this way, as represented in the engraving (see Plate I., fig. 6), the diseased tissue is converted into a compact mass of cells, which to the unpractised or careless observer seem to have no special arrangement, and to be all of the same kind; if, however, they are more critically examined it is soon seen that there are two kinds of cellular elements, those of the one kind being at least twice as large as the other, and that the larger cells are grouped together in nests. These nests correspond to the cavities of alveoli, and are in fact clumps of alveolar epithelium. They are distinguishable from the others not merely by their size and well defined outline, but by the fact that most of them contain minute black pigment granules, which occupy their perinuclear spaces in considerable numbers. In comparing them with the alveolar epithelium of healthy lung it is easy to satisfy one's self that their characters are in the main unaltered.

Accumulation of epithelium in the alveolar cavities.

The next stage in the morbid process consists in the fatty degeneration of the whole mass. It is this disintegrative change which gives rise to the appearance of white or yellowish opacity always observed in the centres of the larger nodules. Both the epithelial cells and the parietal new tissue alike participate in it. The nuclei of the latter break up into smaller corpuscles of irregular form, while fat granules appear in great numbers round the nuclei of the epithelial cells, so that the whole is eventually converted into a granular detritus, in which the only well characterised forms are large cells so loaded with fat granules as to resemble conglomerates.

Fatty degeneration of the nodules.

If the changes referred to in the preceding observations have been correctly described they tend to show that, as regards the lungs, the effect of tuberculous inoculation is to give rise to the growth of new adenoid tissue in the interstitial substance which surrounds the smallest bronchioles and constitutes the alveolar walls, and that the change is neither inflammatory in itself nor accompanied by inflammation of the adjoining parts. The elastic fibrous framework of the lung seems to be entirely exempt from alteration, for the trabeculæ may be seen embedded in the new growth in a perfectly natural condition. The adventitia surrounding the arteries is also entirely unaltered, for the arteries are often to be seen in the very midst of consolidation, but separated from it by a distinct layer of unaltered connective tissue; so that it cannot for a moment be admitted that the change originates from the arterial sheaths. The nodular form and disseminated character of the growths seems to me to be partly accounted for by their relation to the terminal bronchioles, for it may be readily understood that a growth taking its start from a

Nature of the morbid process.

* The accumulation of epithelium (or whatever these larger corpuscles may be called) in alveolar cavities is only to be noticed at the marginal parts of each tubercle, the inner parts having no such corpuscles.

bronchiole and extending peripherally would be likely to assume the conical form of that part of the lung to which the bronchiole leads.

4. *Appearances observed in the Liver.*

Increase of weight.

The liver, which in the healthy guinea-pig constitutes from a twenty-fifth to a twentieth of the weight of the animal, often attains a weight two or three times as great under the influence of the tuberculous infection. In one of the animals (No. 22) the organ weighed 46 grammes, that is nine per cent. of its weight. The greatest relative weight was 12 per cent., in guinea-pig No. 16. The mean relative weight of the organ in 10 animals, in all of which the liver was markedly diseased, was 7·8 per cent.

General nature of the lesions observed.

Two kinds of lesion were noticed; the most obvious, and to the naked-eye observer the most common, consists in the conversion of certain abruptly defined portions of the hepatic tissue into a white opaque material. These isolated masses were met with in various parts of the organ, and varied almost indefinitely in size and form. In the advanced stages it sometimes happened that they were so large that a single mass fully occupied one of the three principal lobes into which the organ is divided; but more frequently they did not exceed a quarter of an inch in diameter. In form they are not altogether unlike the nodules of the lung. Some are completely concealed, but by far the greater number lie immediately under the capsule. Like the pulmonary nodules, they do not change the form of the organ in which they exist, for they are thoroughly incorporated with its tissue. In most of the animals they were found in greatest numbers in the neighbourhood of the sharp margin, and were less numerous in the middle or right lobe than in the left, to which it indeed several times happened that they were exclusively confined.

Islands.

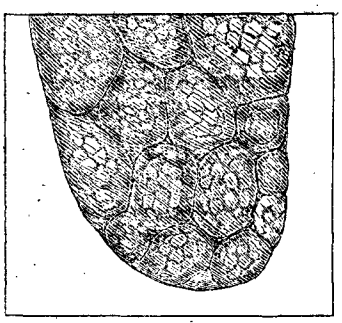
These opaque masses, which I shall hereafter call *islands*, have several peculiarities obvious to the naked eye, which render it easy to distinguish them from all other disseminated deposits. When small they are of a dead white colour, and a firmer consistence than that of the organ itself of which they form part. As they enlarge, the colour changes from white to yellow, and the consistence diminishes, both alterations beginning from the centre; so that in all large islands there is a kernel of soft bile-stained pulp, and a cortex of firm material. Along with the softening there is diminution of bulk, for in the superficial islands the surface becomes so concave that the capsular membrane seems as if stretched over a cavity, hollowed out of the mass. It is further to be noticed that the margin of each island is commonly surrounded by a bright edging of hyperæmia, such as one sees in the human subject around splenic infarcts.

Interlobular growth of adenoid tissue

The above alteration is probably consequent on another less obvious change in surrounding parts of the liver. Both are in fact manifestations of the same process, in the development of which, the lesion now to be described stands first. The healthy liver of the guinea-pig is of an even red colour, resembling that of muscular fibre, but somewhat deeper. The elevations of surface which correspond to the acini can be made out on its external surface when the organ is so placed as to reflect a pencil of light to the eye, but there is no perceptible difference of colour between the lobules and the interlobular spaces. As soon, however, as the organ becomes diseased its size increases while its colour becomes paler. On more attentive examination the paleness is seen to be very unequally distributed, occurring here and there in patches of grey mottling, especially

in the neighbourhood of the islands, if any exist. On making sections of such a liver the mottling is even more apparent than on the natural surface. The grey parts obviously differ in appearance from the islands; while the islands are absolutely opaque the mottling is semi-transparent. To the practised eye the one conveys the idea of a living growing tissue, while the other suggests fatty degeneration or necrosis.

As the process advances, two important characters manifest themselves. First, the organ changes its form. This change is of such a kind as to remind one of the hobnail or cirrhotic liver of human pathological anatomy, a resemblance which, however, is only partial. Each lobe is seen to be divided by deep furrows extending in various directions across its under surface, into prominent nodosities, the general form and character of which may be judged of by the accompanying sketch. The second consists in the extension of the mottled appearance to the whole of the diseased and enlarged organ. When this has taken place it becomes possible, even with the naked eye, to satisfy one's self that the pale parts are interlobular, and that the less altered points correspond to acini.



Change of form of the organ which results from it.

Interlobular mottling of the natural and sectional surfaces.

Microscopical Dissection.—The microscopical examination of the liver in disease is beset with difficulties. My study of the changes above described is as yet incomplete. It is, however, sufficient to enable me to draw some important conclusions as to the relations with the other lesions observed.

Minute anatomy

The islands contain scarcely any elements foreign to the structure of the liver. Each consists in its unsoftened state of a certain number of acini in an anæmic condition. The softening is a process of retrogressive change. The tissue loses its vitality apparently from want of blood. The gland cells eventually undergo fatty degeneration, and become disintegrated; but, evidently, this is not the beginning of the change, for in islands of recent growth and inconsiderable extent the cells are in a natural condition.

of the islands;

The grey interlobular deposit consists of adenoid tissue. To investigate it, it is absolutely necessary to harden the organ in solution of chromic acid. A good general view of the distribution and arrangement of the new growth may be obtained by making a large and moderately thin section through the whole of a diseased lobe, so as to cut across the channels in which the duct and vessels are contained, and examining it in glycerine with a low power. It is then seen that the new material forms masses which are so arranged in relation to the bile ducts that each seems to be surrounded by a zone of transparency. In pursuing the investigation with a higher power it is not difficult to satisfy one's self, even in fresh sections, that this arrangement is not confined to the larger ducts, but extends to those smaller ramifications which are designated *ductus interlobulares*—ducts scarcely exceeding $\frac{1}{1000}$ of an inch in diameter, the cellular lining of which assumes transitional forms intermediate between epithelium and liver cells. In fine sections of hardened liver the following facts can be made out:—

of the interlobular growth.

The grey semi-transparent material consists of adenoid tissue, that is, of a delicate sponge of transparent connective substance, in the cavities of which minute cells or nuclei are lodged.* The diameters of these

* See Minute Anatomy of pulmonary lesions, p. 7.

cavities are seen on section to be about $\frac{1}{1000}$ of an inch. They communicate with each other in all directions, being bounded by membranous septa. The nuclei have a mean diameter of about $\frac{1}{4000}$ of an inch. They are uniformly spheroidal, retaining their rounded contour even after the addition of dilute acetic acid. They are so firmly kept together by the connective substance that it is difficult to examine them apart. So far as can be ascertained most of them seem to be surrounded by a cell wall, others by irregular masses of transparent material, which may be probably regarded rather as bits of interstitial substance than as vesicular membranes, while others again seem to be the centres of stellate or caudate fibre corpuscles. (Plate I. fig. 1.) The relation between the adenoid tissue and the ducts and vessels resembles that which is seen in the lung. In every section of an interlobular grey mass one or more bile ducts can be seen lined with characteristic epithelium, and closely surrounded by masses of adenoid tissue. As was observed with reference to the bronchial tubes, so in the liver, the epithelium of the bile duct is entirely unchanged. The relation of the new tissue to the hepatic arteries is similar. The arteries are embedded in it, but are not themselves altered, nor do I see any ground for the belief that the disease commences in their sheaths.

Relation of the two lesions to each other.

The relation between the interstitial new growth and the islands is not so clear as could be wished. The absolute whiteness of the islands in their early state seems to indicate that they are entirely cut off from the circulation. It cannot be supposed that this is due merely to the obstruction of the hepatic arteries by the development of adenoid tissue around them, for in several instances I have met with livers in which no islands existed, notwithstanding that the new growth evidently constituted the greater part of the bulk of the organ. The only explanation that suggests itself to me is that in those acini which are surrounded by new growth, the intralobular circulation is so compressed as to render them anæmic; for it is not difficult to understand that in a portion of liver which is the seat of adenoid degeneration such lobules as remain in a comparatively unaltered condition will be likely to become anæmic. However this may be, it is evident that an island once formed is as much out of the circulation as an embolic infarct in the spleen or kidney, which it resembles in being bordered by a ring of venous congestion.

5. *Appearances observed in the Spleen.*

General nature of the lesions observed.

The morbid appearances observed in the spleen as examined with the naked eye are of the following nature. The organ may be enlarged without appreciable change of structure, or may at the same time exhibit on section disseminated miliary grains which appear to be malpighian corpuscles. More frequently there is evidence of new growth in the form of rounded projections of its external surface, the pale whitish grey colour of which contrasts strongly with the natural redness of the organ. These nodular prominences vary both in size and arrangement.

Increase of weight.

In its natural state the spleen of a guinea-pig is about half an inch long, and weighs from half a gramme to a gramme, that is, about one-thousandth of the weight of the body. In inoculated animals its size and weight are enormously increased. Thus in ten cases of well-marked disease the average weight was found to be 1·1 per cent., that is more than ten times its weight in health. The heaviest spleen observed weighed $9\frac{1}{2}$ grammes, that is 27 times its natural weight. Another weighed 8 grammes, and measured more than two inches in length. The organ was enlarged with or without structural alteration in 20 out of the 21 animals. In the exceptional case its weight was normal. As,

however, the animal died in my absence, and was not examined by myself, I cannot state positively that it was not diseased.

In nine of the 21 infected animals there was simple enlargement without appreciable change of structure. In two of these no granulations could be distinguished, the sectional surfaces appearing homogeneous. In the rest they were obvious, but their size scarcely equalled that of a millet seed. By microscopical examination I was unable to detect any structural peculiarity. Of five of these enlarged but otherwise healthy spleens the respective weights were 3·1 grammes, 5·6, 6·3, 8·3, and 9·5 grammes. The other two were not weighed, but one of them measured nearly two inches and a half in length.

Aggregate miliary nodules.

In nine animals the external surface of the spleen was beset with miliary nodules, which projected considerably, and on making sections it was found that similar rounded masses were scattered throughout the organ. These nodules possess a very firm consistence, and have the characteristic semi-translucent appearance of grey tubercle, so that a section of the organ has a striking resemblance to a section of hyperæmic and airless human lung beset with miliary granulations. On cutting into them it is found that the smaller nodules are transparent throughout, but that each of the larger ones exhibits a central opacity. They are surrounded by the natural tissue, which exhibits no appearance of hyperæmia, and can be readily enucleated from it without carrying with them any adhering spleen pulp.

Conglomerate nodules in masses.

In two of the animals the nodules were of the same general character, but instead of being disseminated throughout the surface and substance of the organ they were aggregated in groups in different parts. Each of these groups gave rise to a circular projection which assumed a form similar to the so-called tubercles which are met with in cancerous disease of the human liver. In all of them the margin was more prominent than the centre. On making sections of these tuberosities, each was shown to be due to a mass of the same semi-transparent material as that which formed the smaller nodules. Most of them projected on the external or convex side of the organ. As, however, their diameters were equal to its thickness, they could also be felt and seen on its concave aspect although they were not so prominent. The sectional surfaces were irregularly mottled with transparent white, opaque yellowish white, and red; the first being most abundant towards the circumference of the nodosity, the second in the central parts—a fact which seemed to indicate that each tuber is produced, not by the extension of a single nodule, but by the growth of a number of nodules round a previously existing central mass. The sections further showed that in these animals the white material was not separated from the healthy structure by so circumscribed a line as in those cases in which the deposit assumed a nodular form. For this reason the masses could not be readily enucleated.

Sanguineous infiltration.

In one of the animals (No. 14) the condition of the spleen was exceptional. It exhibited two or three nodules of the usual grey colour and firm consistence; but in addition several black red patches, of irregular contour, and very slightly depressed below the general surface of the organ, presented themselves. On making sections it was found that the splenic pulp was in these parts infiltrated with coagulated blood. The organ was placed in chromic acid for examination, but was accidentally spoilt. It weighed three grammes. The morbid appearances in the lungs and liver of the same animal were well marked.

Minute anatomy of the nodular growths.

Microscopical Dissection.—In my examination of the nodules in the recent semi-transparent condition which is most frequently observed, I have been unable to detect any characters by which their

elements can be distinguished from those of the malpighian corpuscles. I have, however, obtained no evidence that they actually originate from previously existing malpighian bodies, or that they have any connexion with arterial branches.* The structure which they exhibit is strictly analogous to that of the adenoid growths already described, and particularly to those which are found in the liver. Fine sections show that each nodule consists of cellular elements embedded in the holes of a vesicular matrix. The paleness of the whole mass is owing to the absence of those venous dilatations to which the spleen owes its peculiar colour, and especially of the blood pigment granules which the sinuses contain in considerable number. In nodules which are opaque in their centres the microscopical appearances resemble those observed in the central softenings of the pulmonary nodules. The change which the opacity indicates is due to the breaking up of the nuclei, and the existence around and among them of innumerable fat granules. In several instances I have found, in making sections of nodules with opaque centres, that the degeneration was not only fatty but calcareous. Under the microscope the calcareous deposit had the form of angular or botryoidal grains. (Plate I., fig. 10.). On the addition of dilute hydrochloric acid to these masses they disappeared with effervescence, leaving a granular fatty detritus behind them.

In the formation of nodules in the spleen, as in the lymphatic glands, we have an example of a process which seems to stand midway between hypertrophy and new growth. The original structure of the nodule cannot be distinguished from that of the tissue in which it originates, *but its development is different.* Normal in its anatomy, it proves itself to be morbid by undergoing fatty degeneration and necrosis.

6. *Appearances observed in the Kidneys.*

Of the 21 animals one only exhibited morbid changes in the kidney. In this case the lesion consisted in the existence of two or three nodules as large as hemp seeds in the cortical substance. These were of firm consistence, and in their microscopical characters resembled those found in the spleen. They were not examined with the microscope.

7. *Appearances observed in the Internal Lymphatic Glands.*

In all cases in which there was disease of the thoracic or abdominal viscera, the internal lymphatic glands were found to be affected. The alteration consisted in enlargement and induration, with caseous degeneration. Neither suppuration nor softening were observed in a single instance. The degree in which the several groups of glands were enlarged appeared to be invariably dependent on the extent and progress of the morbid changes which had taken place in the organs from which they received their tributaries. In those cases in which the lung, for example, remained healthy, although other organs were diseased, the bronchial glands were also found in a natural condition; but in cases like Nos. 21 and 22, in which by far the greater part of the parenchyma of the lung was the seat of interstitial induration, the bronchial glands formed a mass in the upper part of the thorax, consisting partly of the indurated and enlarged organs themselves, partly of

* If it were true, as is now held by many pathologists, that all tuberculous granulations originate in the sheaths of the minute arteries, the resemblance between a splenic malpighian corpuscle and such a granulation would be complete, each of them consisting of a dilatation of the tunica adventitia, filled with lymph corpuscles.

condensed cellular tissue, by which the vessels and other organs contained in the posterior mediastinum were matted together. In a similar manner the size and hardness of glands in the gastro-hepatic omentum afforded a sure indication of the state of the liver, with which in the more advanced cases they were connected by a cord of induration. The agminated glands of the small intestine, and particularly the large patch which is always found close to the ileo-cæcal valve, appeared to me to be usually healthy. Sometimes the follicles were enlarged, in which case enlargement was also found of the corresponding mesenteric glands.

8. *Appearances observed in the Peritonæum.*

These appearances can be best studied in the mesentery and in the gastro-hepatic omentum. They were met with only in a small proportion of the animals examined. On spreading the diseased membrane on a plate of glass it can be made out even with the naked eye that its surface is scattered with minute granulations; and on examining the specimen under a low power it at once becomes manifest that these granulations have a special relation to the vascular branches, and are only to be found in their immediate neighbourhood. The nodules are round or oval, and vary indefinitely in size. I have seen none which exceeded a large pin head in diameter, while others are so small that they can only be discovered by the microscope. Here and there they are so numerous that the vessels resemble, as seen by transmitted light, necklaces of dark beads, some of which look as if they were strung on the artery, others as if they were attached to one side of it.

Their structure and true relation to the arteries is as follows:—They consist of corpuscles which have the same character as those which constitute the new growths in the liver and in other organs. Near the external surface of each granulation, some of the corpuscles are spindle-shaped, so that they are undistinguishable from the nuclei of the peritonæal connective tissue. But those which form the mass of the growth are oval or spheroidal. They are held together by a structureless stroma, which, however, is much less obvious than in the liver and other parenchymatous organs.

Although, as above stated, the granulations are always to be found in the closest relation with vascular branches, it does not appear that they can be regarded as outgrowths of the arterial adventitia. From the examination of those growths, which are to be found on arteries scarcely larger than capillaries, one might easily be led to an opposite conclusion, for these vessels present an appearance which cannot be distinguished from that so frequently seen in the pia mater when that membrane is the seat of tuberculous disease. But in granulations attached to arteries from a twentieth to a thirtieth of a line in diameter, it appears to me evident not only that the newly formed corpuscles are not identified with those of the tunica adventitia, but that they lie altogether outside of it, so that that structure can be traced between the granulation and the muscular coat of the vessel. The relation between the granulations and the vessels can be easily understood if it is borne in mind that all the larger mesenteric and epiploic arteries, along with their accompanying veins and nerves, are inclosed in cylindrical sheaths of areolar tissue loaded with fat cells. It is in these sheaths that the granulations are situated, hence it follows that they lie among the fat cells, and are in contact with them. Around the smaller vessels the areolar sheath cannot be distinguished from the adventitia, and hence the nuclear proliferations with which they are encrusted look as if they formed part of the vascular wall.

APPENDIX.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

Observation X. Inoculation of diseased tissue of supra-renal capsules.

OBSERVATION RELATING TO THE INOCULATION OF DISEASED TISSUE FROM THE SUPRA-RENAL CAPSULE OF A PATIENT AFFECTED WITH ADDISON'S DISEASE.

As the morbid process which occurs in the affected organs in this disease is regarded by some pathologists as distinct from the tuberculous, this experiment is separated from the preceding, although the results were identical.

OBS. X., May 29th.—Two guinea-pigs were inoculated with grey, semi-transparent material, from the supra-renal capsule of a female patient, aged 19, who died, under the care of Dr. Murchison, in Middlesex Hospital, affected with Addison's disease. The following were the most important lesions. The hair exhibited the usual variations of colour, the skin was anæmic but not discoloured, but there were dark patches on the inside of the left cheek. There was an old fibrous adhesion between the apex of the right lung and the pleura, and a similar adhesion of its diaphragmatic surface. The apices of both lungs were puckered and cicatrized, and contained small indurations, with calcareous degeneration. On the left side there was a small cavity surrounded by induration. In other respects the lungs and pleuræ were normal. The bronchial glands were enlarged and pigmented. The solitary and agminated glands of the lower part of the ileum were enlarged and opaque. Similar appearances were observed in the stomach and duodenum. The mesenteric glands were also enlarged and indurated. The supra-renal capsules were much enlarged and indurated, and exhibited a nodulated form. On section they were found to consist of semi-transparent grey material, the sectional surfaces of which showed irregular patches of yellow opacity.

No. 23. Died 36 days after inoculation. *Inoculation wound:* A flattened tumour as large as a fourpenny-piece, showing on section indurated cellular tissue, scattered with minute opaque grains of yellowish white material (caseous abscesses). *Lungs:* Weight 3·3 grammes. Numerous disseminated nodules, grey and gelatinous in their centres, pigmented marginally, all of them minute. Most are sub-pleural, but many are scattered throughout the substance of the organ. *Liver:* Weight 15·4 grammes; relation of actual to normal weight 3 : 1.* General interlobular mottling of the whole organ, the acini being separated from each other by a grey reticulum, which in some parts is so abundant that the intervals are reduced to mere dots of redness, while in others they entirely disappear. The sectional surfaces exhibit a similar mottled aspect, the grey appearing more transparent than it does externally. One or two islands only are observed. *Spleen:* Weight 1·5 grammes; relation of actual to normal weight 12 : 1. Tissue apparently natural. State of lymphatic glands not noted.

No. 24. Died 39 days after inoculation. *Lungs* perfectly healthy. *Liver:* Numerous minute islands, both superficial and in the substance of the organ. *Spleen:* Weight 2·2 grammes; relation of actual to normal weight 15 : 1. The tissue was apparently natural. On its external surface, and scattered throughout the tissue, were numerous prominent semi-translucent miliary nodules. These nodules were used for inoculating other animals.

From this experiment it is evident that no distinction can be drawn between the effects of inserting the material which constitutes the induration of the supra-renal capsules in Addison's disease, and of the

* It is assumed, as stated above, that the relative weights of the organs in the guinea-pig, the weight of the whole body being 100, are—lungs, 1; liver, 4; spleen, 0·1.

inoculation of tubercle. This conclusion was confirmed by the results of re-inoculation. The value of the experiment, however, is somewhat diminished by the fact that in the lungs of the patient from whose body the material was obtained there were indications of obsolete tubercle.

SECOND SERIES.—EXPERIMENTS RELATING TO THE INOCULATION OF MATERIAL FROM THE DISEASED ORGANS, OR OF BLOOD OF ANIMALS PREVIOUSLY INOCULATED.

Secondary inoculations.

Observation XI. Inoculation of diseased tissue from spleen.

OBS. XI., June 11th.—Three guinea-pigs were inoculated with material of nodules in spleen of No. I.

No. 25. Killed 119 days after inoculation. *Wound* contains pus, and is surrounded with induration. Numerous masses of caseous material embedded in indurated connective tissue (old abscesses), but no abscesses containing fluid pus, were found in the subcutaneous tissue in the neighbourhood, over a space extending from the dorsal spines towards the axilla. Enlargement, induration, and opacity of the subcutaneous glands, particularly the scapular and tracheal glands of the same side as the wound. *Lungs:* Very numerous equally disseminated nodules, many not larger than pin heads. They are grey centrally, pigmented marginally, many having shreds of lymph attached to their sub-pleural surfaces. Intervening parenchyma pale. *Liver:* Weight 31 grammes; relation of actual to normal weight 1·5 : 1. No islands. Interstitial deposit of grey semi-transparent material abundant, but very unequally distributed. In the left lobe it assumes the form of nodular growths as large as hemp-seeds; some of them are softened centrally and contain opaque material of creamy consistence. *Spleen:* Weight 3·7 grammes, relation of actual to normal weight 7 : 1. Concave surface smooth. On the convex aspect of the organ, conglomerate nodular masses of three to four lines in diameter exhibiting previously described characters.

No. 26. Killed 87 days after inoculation. *Wound* contains no pus. Two small abscesses in its neighbourhood, the contents of which are caseous. Scapular gland of the same side enlarged, indurated, with partial caseous degeneration, the rest of the gland being of semi-transparent appearance. Other subcutaneous glands not affected. *Lungs:* Numerous and equally disseminated nodules, the largest little more than half a line in diameter. They differ from those previously observed in the complete absence of pigment. *Liver:* Weight 21 grammes; relation of actual to normal weight 2 : 1. A few small islands along sharp margin of left lobe, otherwise healthy. *Spleen:* Weight 6 grammes; relation of actual to normal weight 22 : 1. One or two minute nodules along outer margin. Tissue apparently healthy, but unusually firm. Malpighian corpuscles not distinguishable. Bronchial and hepatic glands enlarged and indurated.

No. 27. Died 77 days after inoculation. *Wound* contains a quantity of pus. There are no abscesses in its neighbourhood. Scapular gland of the same side enlarged and indurated, not softened. *Lungs:* Disseminated nodules of unusual hardness occur in different parts; one in the lower lobe of the left lung, as large as a hemp seed, contains a central cavity, and another in the same lung is grey and solid. There are five similar nodules in the right lung. *Liver:* Weight 21 grammes; relation of actual to normal weight 1·3 : 1. Several islands in each lobe, the largest two lines in diameter. Many of them exhibit softening and bile staining in their centres. Each island is surrounded by apparently healthy liver tissue. In addition to the nodules the bevelled edge of one of the lobes of the liver is completely converted into the same material as that which forms the islands. *Spleen:* Weight 3·5 grammes; relation of actual to normal weight 11 : 1. Innumerable miliary nodules, the largest a line in diameter, on convex surface, which are so close to

each other that scarcely any of the natural structure of the organ can be seen. They are scattered in corresponding abundance throughout its substance.

In this observation, in which the period intervening between inoculation and dissection was longer than before, the retrogressive changes by which the disease would probably have undergone spontaneous cure under favourable circumstances were seen in each case.

Observation XII. Inoculation of diseased tissue of spleen.

OBS. XII., June 25th.—Three guinea-pigs were inoculated with material of nodules in spleen of No. 2.

No. 28. Died 16 days after inoculation. A sub-peritoneal abscess existed between two lobes of the *liver*, and there were two other abscesses in the gastro-hepatic omentum. The other organs were healthy. The liver and spleen were of the normal weight.

No. 29. Died 22 days after inoculation. *Wound* contains pus. The subcutaneous cellular tissue and panniculus from the vertebral spines to the middle line—that is over the whole left flank—are scattered with minute circumscribed abscesses. The glands in both axillæ are enlarged and softened, some of them being converted into abscesses containing a quantity of creamy pus. The left inguinal glands are also enlarged and softened. *Lungs:* Disseminated nodules, all with one exception, smaller than pin heads. In the left lung 24 were counted, six in the lower and 18 in the upper lobe; in the right lung 40, 18 in the lower lobe, 10 in the middle lobes, and 12 in the upper. The larger nodules project considerably, having grey centres and almost black margins. *Liver* of natural weight. Innumerable islands, all of which are edged with a deep margin of injection, scattered over the surface and throughout the substance of the organ. Tissue otherwise natural. *Spleen:* Weight 0·7 gramme; relation of actual to normal weight 1·4 : 1. The organ is beset with minute miliary nodules.

No. 30. Killed 148 days after inoculation. *Wound* cannot be discovered. There is no induration of the subcutaneous cellular tissue, and there are no abscesses. The scapular gland of the left side is much enlarged and indurated, but not softened. The other axillary glands are also enlarged; other lymphatic glands normal. *Lungs:* A few disseminated nodules, none larger than one-fifth of a line in diameter. *Liver* perfectly healthy. *Spleen* contains numerous semi-transparent nodules. The animal was inadvertently not weighed.

Observation XIII. Inoculation of blood of diseased animal.

OBS. XIII., June 25th.—Three guinea-pigs were inoculated with blood taken from the heart of No. 2 immediately after it was killed. The mode of inoculation was the same as in the other experiments, not more than a drop of blood being employed.

No. 31. Died 80 days after inoculation. *Wound* could not be discovered; there was no subcutaneous induration. The tracheal and submaxillary glands on both sides of the neck are enlarged and indurated externally, softened and pulpy in their centres. The axillary and inguinal glands are healthy. *Lungs:* Four or five disseminated nodules, smaller than pin heads in the right lower lobe; two or three in the right upper. Two nodules of larger size in the left lung. *Liver* not weighed; apparently not enlarged. Five or six characteristic islands, varying in diameter from half a line to a line and a half, softened and bile-stained in their centres, and edged with injection, are observed. *Spleen:* Four or five conglomerate nodular masses project on the convex surface of the organ.

No. 32. Killed 105 days after inoculation. *Wound* contains pus, and is surrounded by induration. Numerous disseminated abscesses in subcutaneous cellular tissue. Right scapular gland much enlarged and softened. Tracheal glands slightly enlarged. Inguinal glands enlarged

and softened. *Lungs:* Numerous disseminated nodules as large as pin heads. *Liver:* Weight 33 grammes; relation of actual to normal weight 1·3 : 1. A grey interstial nodule in the middle lobe, similar to that observed in No. 25. *Spleen:* Weight 3 grammes; relation of actual to normal weight 5 : 1. It contains conglomerate nodular masses.

No. 33. Died 130 days after inoculation. *Wound* is open, but contains no collection of pus. The surrounding subcutaneous thickening is less than usual. There is a subcutaneous abscess over the gluteal muscles on the right side. Its wall is extremely thin, and it contains cheesy pus. Scapular glands large and indurated, but less enlarged than usual. Tracheal glands in the same condition. *Lungs:* Disseminated nodules somewhat larger than usual, exhibiting much central opacity. *Liver:* Weight 45 grammes; relation of actual to normal weight 2·7 : 1. No islands. Interlobular mottling of the whole surface with characteristic alteration of form. On microscopical examination the interlobular adenoid growth was found to be abundant in every part of the organ. *Spleen:* weight 10·2 grammes; relation of actual to normal weight 25 : 1. It is smooth and of natural form. In section some parts appear pale, others intensely hyperæmic, but there are no nodules. The bronchial and hepatic glands and those of the splenic omentum are enlarged and indurated.

Observation XIV. Inoculation of diseased tissue from spleen.

OBS. XIV., July 7th.—Two guinea-pigs were inoculated with material from the spleen of No. 24.

No. 34 (Notes by Mr. David Guillod). Died 35 days after inoculation. *Wound* contains cheesy material, surrounded by induration; no abscesses. Axillary glands much enlarged, with cheesy degeneration, but no suppuration. *Lungs* healthy. *Liver:* Weight 14·5 grammes; relation of actual to normal weight 7 : 1. Ten or twelve characteristic islands two lines in diameter; tissue of organ apparently healthy. *Spleen:* Weight normal. Two nodules as large as pin heads.

No. 35. The body was not discovered till August 31st, that is two or three days after death, and 55 days after inoculation. It was putrid. The *spleen* contained characteristic deposits, but the other organs appeared healthy.

Observation XV. Inoculation of apparently healthy tissue of supra-renal capsule of a diseased animal.

OBS. XV., July 7th.—Two guinea-pigs were inoculated with material from the apparently healthy supra-renal capsules of the same animal, No. 24.

No. 36. Died 114 days after inoculation. *Wound:* Breach of continuity at point of inoculation covered with a scab, about half an inch from which is a mass of thick, tough, cellular tissue adherent to the integument, riddled with interstices containing caseous pus. Scapular, tracheal, sub-maxillary, and inguinal glands of left side enlarged and softened. No enlargement of glands on right side. *Lungs:* Five or six nodules in left lung, one of which near the apex is as large as a hemp seed. It is hard externally, softened centrally, and scarcely projects above the surface. The other nodules are much smaller. Numerous similar nodules in the right lower lobe. The right upper lobe adheres loosely to the pericardium and wall of the chest by a layer of granular lymph, which is in some parts continuous, in others consists of subpleural granulations scarcely distinguishable without a lens. *Liver* of natural size, one or two small islands in the right lobe. *Spleen* much misshapen, and about 20 times its natural size. Seven conglomerate nodular masses can be distinguished; the largest of these, occupying the centre of the organ, is as wide as a threepenny-piece; its depressed and softened centre is white, the convex margin being of a reddish white.

Its sectional surface is white superficially, white, mottled with red, more deeply. Yellow opacities occur, which grate against the knife. In the smaller nodules there is no grittiness. Bronchial glands enlarged and indurated; their sectional surfaces exhibit yellow and opaque patches. The condensed cellular tissue around the æsophagus is beset with white miliary nodules. Hepatic glands also enlarged.

No. 37. Killed 136 days after inoculation. *Wound*: Over the upper dorsal spines was a mass of indurated cellular tissue, containing much fat in its areolæ; on puncturing this mass pus escaped. Both scapular glands enlarged, particularly the right. The other axillary and the tracheal glands were also enlarged and indurated. Their sectional surfaces were for the most part transparent, but showed opaque patches, which grated against the knife. *Lungs:* Numerous disseminated sub-pleural nodules, all of which were semi-transparent. *Liver:* No islands; semi-transparent interstitial deposit exists throughout the organ, most abundantly in the left lobe, where it assumes a nodular form. *Spleen* contains several conglomerate nodular masses, the largest of which is three lines in diameter. Hepatic and bronchial glands enlarged and indurated.

Tertiary inoculations.

THIRD SERIES.—EXPERIMENTS RELATING TO THE INOCULATION OF MATERIAL FROM THE DISEASED ORGANS OF AN INOCULATED ANIMAL OF THE SECOND SERIES.

Observation XVI. Inoculation of diseased tissue of spleen.

OBS. XVI., October 8th.—Four guinea-pigs were inoculated with material from the spleen of No. 25.

No. 38. Killed 56 days after inoculation. *Wound:* No suppuration, and very slight induration. Scapular gland much less enlarged than in animals previously examined; other axillary glands also slightly enlarged. Neither were softened. *Lungs* and *Liver* healthy and of natural weight. *Spleen* not enlarged; contains two miliary nodules, and its malpighian corpuscles are distinct, and apparently enlarged. The animal was a large boar, and in good condition.

No. 39. Killed 56 days after inoculation. Scapular gland of left side somewhat enlarged, and slightly softened. Other subcutaneous glands healthy. *Lungs:* Characteristic disseminated nodules, varying in size from one-fifth of a line to a line in diameter, the larger ones having opaque centres, the former being transparent throughout. All exhibit the usual marginal pigmentation. They were carefully examined, and found to present the structural characters described at p. 7. *Liver:* Weight 19·5 grammes; relation of actual to normal weight 1·5 : 1. No islands. The external surface exhibits patches of grey mottling, which are particularly abundant near the sharp margins of the right lobe. *Spleen:* Weight 2 grammes; relation of actual to normal weight 6 : 1. Convex surface beset with miliary nodules of remarkable transparency. Bronchial and hepatic glands, particularly the former, enlarged and indurated.

No. 40. Killed 81 days after inoculation. *Wound* unhealed and surrounded by slight subcutaneous condensation and thickening. A small abscess, two lines in diameter, between panniculus and skin, not connected by a cord with the wound, from which it is half an inch distant. Another similar abscess at the same distance, leading to which a cord can be distinguished. Of these two abscesses the former contains caseous, the latter fluid pus. Left scapular gland enlarged and suppurated; right scapular and one or two tracheal glands enlarged and caseous. Other subcutaneous glands healthy. *Lungs* healthy. *Liver:* apparently healthy. Traces of interstitial deposit. *Spleen:* Conglomerate nodular deposits, none exceeding three lines in diameter.

The nodules of which they are composed are opaque internally, semi-transparent externally.

No. 41 is still under observation.

In the preceding experiments of the second and third series the morbid appearances differed in no important respect from those observed in animals inoculated directly with tuberculous material. It is, however, worthy of notice that, although in some of the animals the subcutaneous lesions were quite as extensive as in the experiments of the first series, the local effects were on the whole slighter, and in several instances very inconsiderable. It is also worthy of remark, as regards the morbid appearances in the liver, that in two or three animals, particularly in Nos. 25, 32, and 37, the interlobular new growth was so exuberant in some parts of the diseased organs that it formed distinct nodular masses,—a circumstance not before observed. In other animals the grey mottling was entirely absent. I am, however, inclined to anticipate that in the further progress of the inquiry it will be found that, whenever the liver is enlarged, interstitial adenoid growth really exists and could be detected by the microscope, even though to the naked eye there seem to be no indications of structural change.

In concluding this section of my inquiry I draw attention to the following facts, as established with some degree of certainty, and as having an important bearing on the question of the development of the morbid process, that is on the mutual relation of the several lesions to one another :—

1. Suppuration occurs in nearly all cases under the skin at the point at which the tuberculous material is inserted ; and in most, the suppurative process is propagated to the subcutaneous areolar tissue in its neighbourhood. It is, however, not essential to the production of the internal lesions ; for in two cases there was no trace of suppuration anywhere around the wound.

2. In every infected animal the lymphatic glands corresponding to the place of inoculation were enlarged ; usually there was softening ; there was always caseous degeneration.

3. In eight infected animals the lungs were free from disease.

4. The liver was probably in no instance absolutely healthy, but the lesions were very variable, no less in their nature than in their extent.

5. In one animal the spleen appeared to be of natural size and structure. With this exception, the organ was always enlarged. In many animals there was no apparent change of structure. In others there were new growths, which appeared to consist of overproduction of those elements which the spleen has in common with lymphatic glands.

5. The internal lymphatic glands receiving their tributaries from diseased organs were always themselves enlarged, indurated, and caseous.

The results of the three series of experiments now related afford an answer to the first of the questions proposed at the outset, so far as relates to the species of animal used. They show that the inoculation of tuberculous matter produces in guinea-pigs morbid changes so constant both in their anatomical character and development that they may be regarded as constituting a disease ; for in all the organs the appearances observed are much less variable than those we are accustomed to find in idiopathic tuberculous disease of man. The true relation of the human disease to its bestial derivative cannot yet be determined.

The second part of the question cannot be decisively answered at the present stage of the inquiry. Anatomically the disease may be defined as primarily an overgrowth of the lymphatic glands, and of

those structural elements of other organs which they have in common with the lymphatic glands. But anatomical characters afford no sufficient basis for a definition.*

PART II.—PREVIOUS RESEARCHES.

Ever since Laënnec † produced a growth which he regarded as tuberculous, on the forefinger of his left hand, by accidentally scratching it with a fragment of bone while engaged in the post-mortem examination of a patient who had suffered from vertebral caries, the notion that tubercle might be communicated by inoculation has from time to time suggested itself to the minds of various pathologists. It was not, however, until Villemin drew attention to the many facts which render it probable that tuberculosis is the manifestation of a morbid action pervading the whole organism, and that in its development and propagation it is governed by the same conditions as the so-called zymotic diseases, that the subject assumed its present importance. It was the consideration of these facts, and particularly of the close relation which seemed to him to exist between tubercle and a disease peculiar to the horse, viz., farcy, that induced M. Villemin to undertake those remarkable experiments which form the basis of the present inquiry. From these experiments he concluded that tuberculosis must no longer be regarded as a constitutional malady, but as one dependent on a specific infection,—in short, as a zymotic disease.

Since the publication of these results other pathologists in France, England, and Germany have followed in Villemin's track. The fact that a morbid process, having a certain general resemblance to that by which tubercle is formed, is set up in animals inoculated with tuberculous material, has been abundantly proved, but the interpretation given by different observers differs widely. In order as much as possible to separate facts from inferences, and at the same time to furnish the reader with a complete and intelligible view of the present state of the question, I propose to divide the following summary of previous researches into three sections. In the first, the nature of the experiments will be briefly recorded; in the second, an account will be given of the anatomical characters of the lesions observed in inoculated animals; and in the third, of the theories which have been advanced in explanation of them.

SECTION I.—EXPERIMENTS.

M. Villemin's first series of experiments.

On the 5th of December 1865 M. Villemin communicated to the Academy of Medicine of Paris a paper in which the results of the inoculation of ten rabbits were given. In these experiments the material used was always mixed, some of it being grey, the rest caseous. The mode of inoculation consisted in passing the blade of a narrow bistoury under the skin, near the base of the ear, and introducing the material into the wound, after breaking it down with the point of the knife.

The first inoculation of mixed pulmonary (caseous) and intestinal (grey) tubercle was performed on the 6th of March 1865, and repeated in the same animal on the 30th of March and the 4th of April. It was killed on the 20th of June, when "tubercular masses" were found in

* If the chemical nature of that transformation of tissue which gives cheesy yellow tubercle as its result, were more thoroughly understood, it would probably be possible to found a definition upon it.

† Traité d'Auscultation Médiate, 1837, Forbes's Translation, p. 331.

the lungs, and granulations under the peritonæum. On the 15th of July three rabbits were inoculated, the operation being repeated on the 22nd, when a fourth rabbit was inoculated for the first time. About two months afterwards they were killed. "Pulmonary tubercles" were found in each case, and there were also "tubercles" beneath the peritonæum. Three rabbits were inoculated on the 2nd, and again on the 24th of October, on which day a fourth rabbit was inoculated for the first time. In all these animals, which were examined about a month after the second inoculation, granulations, regarded by M. Villemin as tuberculous, were found in the lungs.*

M. Villemin's second series of experiments.

In a second paper, communicated to the Academy on the 30th of October 1866, M. Villemin relates the results of subsequent experiments on 12 other rabbits inoculated with "tuberculous granulations." Four of these experiments failed, three of the animals dying of diffused subcutaneous purulent infiltration only a few days after the operation. In the other, which was killed six months after inoculation, no lesions were found. The animals successfully inoculated were killed from two to six months after inoculation. Tubercle was found in the lungs and other organs, it being observed that in those that lived longest the tuberculous deposits were more or less yellow and softened, whereas in those in which the interval was shorter the deposits were grey.† In the unsuccessful case, M. Villemin attributes the failure to the insufficient evolution of the tubercle employed.

In addition to his experiments on rabbits, M. Villemin has also employed other animals. On the 19th of December 1865 two guinea-pigs were inoculated, one of which was found dead on the 21st of February, the other on the 31st of March. Both exhibited numerous tubercles in the lungs, liver, spleen, and lymphatic glands. About the same period several dogs were inoculated with material of grey granulations. In three that were killed several months afterwards, no traces of tubercle could be discovered. But in the other, which was three times inoculated, and killed five months after the first inoculation, subpleural granulations were found which were regarded as tuberculous. The lungs, however, were perfectly healthy. The result of this experiment was regarded by M. Villemin as doubtful, but on a subsequent occasion (June 24th 1866) he was more successful. The animal was killed three months after inoculation, when characteristic granulations were found in the lungs, liver, kidneys, spleen, and mesentery. In three inoculations of cats no satisfactory results were obtained. The experiments on goats, sheep, and fowls were also unsuccessful.

M. Villemin's secondary inoculations.

On the 30th of April two young rabbits were inoculated with material from the lungs of another inoculated rabbit just killed. One was killed six weeks after the operation, and the other was found dead two weeks later. In the former there were numerous tuberculous granulations in the lungs and spleen. In the latter both lungs were so completely filled with tubercle that scarcely any sound tissue remained. The liver and spleen were also tuberculous. The details of five similar experiments made at subsequent periods will be found in M. Villemin's "Études sur la Tuberculose," pp. 542–545.

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* At the same time with these experiments other animals were inoculated with other morbid products, particularly with pus from phlegmonous abscesses, and from a carbuncle. These experiments were without result.

† The details of these experiments are given at length in the Bulletins of the Academy of the dates corresponding, as well as in M. Villemin's Work, "Etudes sur la Tuberculose," Paris, 1868.

APPENDIX.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

Mr. Simon's experiments.

On the 19th of March 1867, Mr. Simon communicated to the Pathological Society of London, the results of some experiments made by him for the purpose of verifying M. Villemin's statements.

In June 1866, he inoculated 10 rabbits with softening yellow tubercle, taken from the lungs of a patient who had died of phthisis 20 hours before. The following November, nine of them were killed. On dissection, it was found that in five the lungs presented appearances resembling those of tuberculous disease, but that in the others they were healthy. From the masses contained in these lungs, three other rabbits were at once inoculated, of which two were killed in March, 1867. In both there were extensive tuberculous consolidation of the lungs and enlargement of the mesenteric glands, while in one lesions of a similar character were found in the spleen and liver. In commenting on these results, Mr. Simon confined himself to pointing out that the aspect and common physical properties of the product were entirely those which in man we call tubercular, and that although it for the most part resembled yellow tubercle, the small rounded masses seen in the lungs were found, when slightly magnified, to have a semi-transparent grey circumference. The diseased organs were submitted to a committee of the Pathological Society for further examination, who subsequently reported that the masses found in the lungs and other organs resembled crude tubercle in their macroscopical characters, in their minute structure, in the tendency observed in them to induration and earthy degeneration, and finally in their being found in those organs which are the ordinary seats of tubercle.*

Prof. Lebert's experiments.

Inoculation of typical tubercle. Expts. 1-11.

The experiments of Professor Lebert, which relate not merely to the transmissibility of tubercle, but to that of various other inflammatory products and new growths, from man to animals, are divided by him into five groups, comprising 45 experiments. The first group relates to the inoculation of what Lebert regards as typical tubercle. Eleven animals were employed of which five were guinea-pigs and six rabbits. The material used was taken from the bodies of patients affected with phthisis, in whom the lesions were of the following character. In only one case was there acute pulmonary tuberculosis, in three instances there were vomicæ and pneumothorax, associated with pneumonic infiltration and disseminated secondary granulations, some of which were grey and others yellow, both being employed in inoculations. In two cases the pulmonary lesion consisted exclusively in yellow disseminated pneumonic masses with vomicæ; in two others there were chronic pneumonic masses and peribronchitic foci without cavities, while in another there was diffused chronic pneumonia. In the remaining two experiments the material used was taken from the mesenteric glands of a child who had died with pneumonic masses in the lungs and tubercular granulations elsewhere. All of these experiments were successful, nor could any difference in the result be observed, notwithstanding the great variety of the materials employed.

Inoculation of pus. Expts. 12-13.

In the second group, consisting of two experiments, (dogs) pus was injected, not into the cellular tissue but into the jugular vein. In one case the injection was performed four times within three weeks, six grammes being used each time, the last inoculation being followed by diarrhœa and vomiting, and lastly by emaciation, &c. When the animal was killed 34 days after the first injection numerous disseminated abscesses were found in the lungs, and nodules varying in size from that of a pin head to that of a lentil in the liver. The other experiment was

* Trans. of the Pathological Society, vol. xviii., p. 290.

similar, but the results were different. There were "grey semi-" transparent granulations . . . situated partly in the alveoli, partly " between the pulmonary fibres; the apices of both lungs were " adherent . . . The liver contained numerous greyish yellow nodules " of the same constitution and character as those in the lungs."

Inoculation of bronchial and cavernous secretion. Expts. 14–22.

In the nine experiments of the next group bronchial and cavernous secretion was used, six of the patients being affected with chronic pneumonia, the rest with pulmonary gangrene. No granulations were found in the internal organs, the animals dying rapidly, apparently of septicœmia.

Development of lesions resembling those observed after inoculation, in consequence of a surgical operation. Expt. 23.

Next follows a single observation relating to a dog which died three days after the injection of phosphorous oil per rectum, having a fortnight before undergone the operation for biliary fistula (Bernard's operation). In this case "numerous nodules as large as pin heads were found on the " pulmonary pleura, each of which exhibited a central dark blackish " point . . They did not extend to the parenchyma. Numerous small " nodules scarcely as large as pin heads of a pale grey colour and firm " consistence . . . resembling the granulations produced by inoculation " in the animals of the first group, were found in both lungs." On microscopic examination it was found that the nodules possessed the same structure as those existing in animals inoculated with tubercle, " both the cavities of the alveoli and the interstitial tissue being infil-" trated with cells, the intra-alveolar ones being distinguished from the " others by their greater diameter, and the melanin granules which they " contained."

Inoculation of various non-inflammatory morbid products. Expts. 24–34.

The last group comprises experiments with melanotic, sarcomatous, cancroid and cancerous products. The most important results were the following. Three rabbits were inoculated with melanotic tumours of the horse. In one of them which died two months and a half after inoculation, a well marked stellate cicatrix was found at the seat of insertion under which a number of nodules varying in size from a millet to a hemp-seed were seen. These nodules were ascertained to "consist exclusively of small round cells resembling those of lymphatic glands," enclosed in tough connective tissue. They were regarded by Lebert as structurally identical with tubercles.

The two next experiments relate to sarcoma and were without result, excepting in so far that in one of the animals a typical bronchial alveolitis was found. Experiments 33–34 relate to cancroid and carcinoma. They were altogether unsuccessful so far as relates to the communication of cancer, but in one of them appearances resembling tubercle were found in the lungs. Isolated nodules most of which were smaller than pin heads and of a whitish grey colour were found in the lung tissue under the surface of the pleura, the surrounding parenchyma being pale and anæmic. The granulations in the lungs were found to consist of intra-alveolar infiltrations.

Injection of finely pulverized charcoal.

In experiments 35–39 charcoal was injected into the jugular vein. In three instances death occurred from the immediate effects of the injection. In the two other cases the charcoal was found to have penetrated to the pulmonary capillaries, liver, and in one case to the brain. In one of the animals which was killed, three months and a half after, when apparently in good health, two small nodular masses of alveolar infiltration were found, each of which contained a little fragment of charcoal in its centre. Several similar fragments were found also in the adventitia of pulmonary arteries. In the other rabbit, which died 24 days after injection, there were disseminated foci of irritation, so numerous, that they occupied four-fifths of the lung. The sections of the infiltrated parts exhibited fine granulations, just like those seen in

APPENDIX.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

human pneumonia. Microscopic examination showed that the granulations were due to the filling up of the alveoli with a finely granular material containing comparatively few epithelial cells.

Injection of mercury. Expts. 40-45.

In the last six experiments mercury was injected into the veins in five cases, and in one into the trachea. The lesions observed, although of great interest, are not sufficiently relevant to our present inquiry to merit detailed description. In one case, in which death occurred by endocarditis, there was nodular and diffused peri-arteritis, but the alveolar and interstitial tissues of the lung were very slightly involved. Most of the nodules contained quicksilver granules in their centres. Pulmonary suppuration occurred frequently.*

M. Colin's experiments.

M. Colin, in his report to the Academy of Medicine in Paris, on M. Villemin's experiments, relates that in four inoculations made by himself, only one was successful, a result probably attributable to his mode of insertion, which, as he describes it, was certainly ill adapted for the purpose. In subsequent experiments, in which he adopted a better method, the results were nearly as constant as in those of M. Villemin.†

Dr. Roustan's experiments.

Dr. Roustan in his recently published inaugural thesis describes several series of experiments on the inoculation of pulmonary tubercle. In the first series three rabbits were inoculated, one with grey tubercle, one with caseous pneumonia, another with the tissue of tuberculous and softened mesenteric gland. In the second series guinea-pigs were employed. Some of the anatomical results, which are in the main confirmatory of M. Villemin's observations, will be again referred to. In a dog which was twice inoculated, the first time with yellow tubercle, the second time with grey, characteristic tubercular lesions were found in the peritoneum, liver, spleen, supra-renal capsules, and lungs. In another dog, inoculated in the same way, the experiment failed, apparently in consequence of the circumstance that the animal tore out the ligatures with which the inoculation wound was secured, immediately after the operation. In two guinea-pigs in which two grammes of the blood of a phthisical patient were injected under the skin, no result was obtained. In addition to his own experiments, the author relates one important observation made by Dr. Goujon in Professor Robin's laboratory which illustrates the liability of guinea-pigs to spontaneous tubercle, and the rapidity with which the tuberculous lesions are produced by inoculation from animals idiopathically affected. A guinea-pig used for some other experimental purpose was found to have characteristic tubercles in all its organs.‡ Sub-peritonæal granulations of this animal were thereupon inoculated to two others of the same species. One of them died 14 days, the other 18 days after inoculation. In both it was found that the lymphatic glands were enlarged, that the peritonæum was beset with miliary granulations, and that tuberculous nodules existed in the liver, lungs, spleen, and kidneys, which were found on microscopical examination to have the characters of tubercle.§

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* Prof. Lebert and Dr. Oscar Wyss: Beiträge zur Experimental-Pathologie der heerdartigen umschriebenen disseminirten Lungenentzündung, so wie der Uebertragung der sogenannten Tuberculose und anderer entzündlicher und verschiedener neoplastischer Producte von Menschen auf Thiere. Virchows Archiv. Vol. XLI., 1867.

† Colin: Rapport sur deux communications de M. Villemin, ayant pour titre "Cause et Nature de la Tuberculose." Bulletin de l'Acad. de Méd., tome 32, p. 897.

‡ This is the only instance I have met with of the spontaneous occurrence of tuberculous lesions in the guinea-pig, independently of inoculation. Nothing is stated as to the nature of the previous experiments to which these animals were subjected.

§ Dr. A. Roustan, Récherches sur l'Inoculabilité de la Phthisie, Paris, 1867.

Dr. Waldenburg's experiments.

Very recently Dr. Waldenburg, to whose anatomical results I shall have to make further reference, has given a short account to the Medical Society of Berlin of experiments made by him on no less than 80 animals (rabbits and guinea-pigs) relating to the inoculability of tubercle. His experiments are divided into five series. In the first of these, miliary tubercles were employed, which were obtained partly from the lungs and pleura, partly from a tuberculous gland, of a phthisical patient. In 16 animals so inoculated, 10 died within a few days after inoculation, and exhibited no traces of tubercular lesion. In the remaining six the lesions were as follows: "In 1 there was a single "miliary nodule in the lungs, and a small miliary focus in the liver. "In 2 numerous miliary foci in the liver. In 3, several miliary foci "in the lungs, and numerous lenticular cheesy alveolar infiltrations "besides pleurisy. In 4 there were numerous miliary foci in the "lungs, and a mass of lobular pneumonia, besides miliary foci in the "liver and kidneys. In 5 there were numerous miliary foci in the "liver and kidneys, while the spleen was enormously enlarged. In 6 "the mesentery was beset with grey and yellow nodules, varying in "size from that of a hemp seed to that of a lentil; the cæcum, and "particularly its appendices, exhibiting the same appearance. Some "of the intestinal nodules projected from the serous surface, others "broke through the mucous membrane and formed little ulcers on its "surface. Peyer's patches contained large ulcers on a caseous base, "some of which were bordered by miliary nodules. The spleen con-"tained a miliary yellow nodule. The kidneys were degenerated and "exhibited minute white foci. The lungs were healthy. The animal "had lived three months and a half, and nothing was to be found at "the seat of insertion."

The second series relates to inoculations with caseous products. The results were negative. In the third series hypertrophied and cheesy lymphatic glands were employed, which had been removed from a person who was otherwise in good health. Of seven animals so inoculated, four exhibited miliary foci in the liver, and in one there were miliary nodules in the large intestine. In the fourth series pus taken from the inoculation wound of another animal was employed. Of the nine animals two had miliary nodules in the large intestine, one had red hepatisation of the left lung with partial cheesy infiltration of the lower lobe and suppurative pleurisy. In four others there were miliary foci in the liver. In other experiments a great variety of inflammatory products were employed; the results were negative, most of the animals dying very shortly after inoculation.

Subcutaneous insertion of inert matter.

In addition to these inoculations of morbid products, other experiments were made in which materials were introduced under the skin, the effect of which could only be attributed to their mechanical properties. These materials were (1) various tuberculous or other pathological preparations which had been kept four months in spirit, and then steeped in hot water; (2) similar material previously steeped in fuming nitric acid or subjected to prolonged boiling; (3) tuberculous cheesy material intimately rubbed down with aniline blue; (4) aniline blue by itself. In all these experiments the lymphatic glands were enlarged and infiltrated, while miliary nodules were found in the internal organs; when aniline was used, aniline granules could be detected embedded in the nodules. The author states that the structure of these nodules was identical with that of grey tubercle, but the description given is so incomplete that it is not possible to form an opinion upon

the subject. It is stated that the research will be shortly published in detail.*

It is finally necessary to notice two series of experiments both of which were entirely unsuccessful, those of Dr. Feltz of Strasburg, and Dr. Vogel of Dorpat. In the first experiments of the former, nine rabbits were inoculated in the usual way with tuberculous matter. In one of the animals seven or eight minute caseous abscesses were found in the lungs, but in the others no lesions of importance were observed. In another series tuberculous matter triturated with distilled water was injected into the jugular veins. Lesions were produced in various internal organs, which, says the author, "at first had the characters of infarcts, and were subsequently transformed into abscesses." He concludes that the nodules which have been regarded by others as tubercles are in reality inflammatory and produced by capillary emboli.†

Dr. Vogel inoculated a crow, a cat, and a pullet, with tubercle taken from a phthisical patient. None of them exhibited the slightest signs of tubercle.‡

SECTION II.—ANATOMICAL RESULTS.

The only detailed or exact anatomical descriptions of the lesions observed in animals inoculated with tuberculous products are those given by Professor Lebert of Breslau, in the two papers already referred to. The accounts given by Villemin refer only to the macroscopical appearances of the alleged tubercles, so that it is not possible to state whether the lesions were always of the same nature, or in what respects they differed from those which we have ourselves observed. But in the minute exactitude and clearness with which Lebert has described his observations, he has given an example which cannot be surpassed.

Subcutaneous lesions; Lebert's results.

Subcutaneous Lesions.§—It will be remembered that in 11 experiments, typical tubercle or pneumonic consolidation around tubercle was employed. In these 11 experiments it was found that in all there were signs of irritation at the seat of inoculation, and that in several instances the local effects were out of proportion with the physical properties of the material introduced and the quantity used. These effects consisted in induration and thickening of the subcutaneous areolar tissue, suppuration of the wound, and the formation of numerous abscesses or foci of suppuration in the neighbourhood. In some instances abscesses were also found at a distance. In one case miliary nodules were found around the wound which are stated to have had all the characters peculiar to tubercle, and to have consisted of rounded partly nucleated cells, which generally varied in diameter from 0·0125 to 0·015 millim., but were sometimes larger. The author regards this as a result altogether exceptional. M. Villemin observed in his inoculations that about a week after the operation a nodosity appears at the seat of the puncture "which communicates to the finger exactly the sensation of indurated chancre." This enlarges progressively, and eventually a little opening forms by which caseous matter

Villemin's results.

* Dr. Waldenburg; Die Impfbarkeit der Tuberkulose, Allg. Medicin. Central-Zeitung, 18. Dec., 1867.

† Dr. V. Feltz, Résultats d'Expériences sur l'Inoculation de Matière Tuberculeuse, Gaz. Méd. de Strasbourg, Oct. 25, 1867.

‡ Deutsches Archiv für klinische Medicin, July, 1866.

§ In stating the anatomical results arrived at by Professor Lebert and M. Villemin, the same order will be followed which I have adopted in the description of my own experiments.

escapes. Occasionally the opening closes immediately, the nodule having slightly shrunk, but subsequently reappears again to empty itself after a longer or shorter period. The tumour sometimes attains a considerable volume especially in animals inoculated from others. In cutting through it the section exhibits the aspect of a large tubercle in the subcutaneous cellular tissue. Around the principal mass a certain number of minute yellowish miliary granulations are found which are infiltrated to a considerable distance in the connective intermuscular tissue; sometimes several are agglomerated so as to form nests. The areolar tissue in which these granulations are formed is usually reddened and injected, and occasionally thickened and lardaceous. In structure and development they resemble the tubercles of the lung.

Subcutaneous lymphatic glands; Lebert and Villemin.

Subcutaneous Lymphatic Glands.—Lebert describes two kinds of lesion. In general he observes that the lymphatic glands become enlarged and suppurate. This enlargement and softening to which he applies the term infiltration, appear to him to arise merely from "hyperplasia of the lymphatic cells," and accordingly the products of infection (in the glands) do not conform to any exclusive cell-type, nor constitute a single tissue recognizable by the naked eye. But besides this alteration Lebert finds, in infiltrated or softened glands, "small "yellowish nodules which do not undergo suppuration, and have altogether the characters of the (tubercular) nodules" of the internal organs. Villemin, who elsewhere clearly describes that form of tubercular disease of the lymphatic glands in man which assumes the form of granulation, makes no allusion to its occurrence in inoculated animals. The only alterations he refers to, are enlargement, caseous degeneration, and softening. He adds that the diseased glands are usually connected with the seat of inoculation by a cord of induration.

Pulmonary lesions; Lebert.

Internal organs. Lungs.—The only lesion to which Lebert attaches importance, as affording evidence of tuberculous infection, is that of the formation of disseminated indurations which, although they belong to the tissue of the lung, for the most part occupy a sub-pleural position. These he describes as "infection nodules. They vary in size "from that of a speck (*Pünktchen*) to that of a lentil. . . . They usually "project above the natural and sectional surfaces. . . . Even the very "small nodules appear on close examination to be conglomerates of still "smaller ones. Their consistence is sometimes soft, tenacious (*zäh*), and "gelatinous; sometimes firm and hard. Their colour varies from clear "semi-transparent grey, to dark much pigmented iron grey. Many are "almost opaque, the white or yellowish opacity springing from the "centre. In more rare cases the superficial nodules are surrounded by "a greyish red furrow (*Wall*). The nodules consist entirely of cells, "which, however, are firmly adherent both to each other and to the "neighbouring tissues. The alveolar wall is persistent only in the "smallest nodules. Most of them extend to groups of alveoli, the "arrangement of which groups rather expresses spreading by continuity "than the expansion of an individual lobule; so that the nodules do "not form pencil-shaped appendages to the terminal bronchioles."* The cells are usually round; some contain only fine granules, but others exhibit "a distinct nucleus, on the addition of water, and still more "of dilute acetic acid." Their size varies as above stated. The nuclei "are from 0·006 to 0·01 and even to 0·015 millim. in diameter. The "epithelial type of these cells, with their pale colour, cannot be mis-"taken. They contain either numerous minute opaque granules, or more

* Die Knötchen keines Weges pinselförmig den Endästchen der Bronchien aufsitzen.

"refractive fat granules, or even distinct fat. Pigment is often contained "in them in large quantity, *i.e.*, melanine granules between membrane "and nucleus, in such numbers that the body resembles a pigment cell. "Numerous pale young cells without nuclei, not much larger than blood "corpuscles, are found among the others. Remains of alveoli and elastic "fibres are met with in the masses of cells which mark the spread of the "nodule." In addition to these nodules, which he distinguishes as alveolar, "others are met with, consisting of minute cells with smaller "nuclei, and connective tissue cells mixed with spindle-shaped cells, "both in the alveolar wall, in the bifurcations of minute arteries, and on "the external surface of small bronchioles, sometimes mixed with more "diffuse cell-multiplication of the like microscopical constitution, so "that the infective cell irritation has for its consequences alveolitis, "peri-alveolitis, peri-bronchitis, and peri-arteritis." In injected pre-"parations the alveolar capillaries of the nodules contain no blood. In fine sections of hardened lung, says Lebert, these facts can be still more distinctly recognized; and, in addition, cell-multiplication was observed "in the adventitia of the smallest branches of the pulmonary arteries. "In these proliferations all transitions were seen between diffused "connective tissue, more circumscribed groups, and nodules distinctly "visible to the naked eye." Of the change which gives rise to the central softening of the nodules Lebert gives no detailed account. It appears, indeed, as if in his experiments this process had occurred only to a limited extent. But in a later paper, communicated to the Berlin Weekly Journal (January 6th, 1868), he describes the dissection of a guinea-pig, killed four months and a half after inoculation with peritoneal tubercle, in which the softening of the pulmonary nodules had proceeded to the formation of vomicæ.* Lebert has occasionally observed that general bronchial hyperœmia and mucopurulent secretion from the bronchial membrane occurred, consequently on the formation of nodules, in animals in which they were very numerous. In other cases there were pleural adhesions. M. Villemin gives no anatomical description of the pulmonary lesions.

Hepatic lesions; Lebert.

Liver.—Next to the lungs Lebert found the liver the most frequent seat of "infection nodules." In addition to these, he describes as lesions to be carefully distinguished from them, "small white superficial islands "consisting of fattily degenerated liver cells, which resemble nodules, "and measure from one to two millimètres in breadth, and are as much "as two millimètres in depth." When true nodules occur, he finds that they consist of a semi-transparent material, which has the same appearance as those which occur in the lungs, and that they are associated with a more diffused alteration in the structure of the organ, which he describes as "an inflammatory condition," stating that it consists of "a cell multiplication of the interstitial connective tissue of "the organ, in consequence of which many of its lobules become "atrophied." Of these remarkable lesions only one example, however, is given. It is that of a guinea-pig, which had been inoculated four months and a half previously with firm infiltrated pulmonary tubercle of a patient who had died of phthisis in the third stage. The condition of the liver is described as follows:—"The liver is much enlarged, and "weighs 57 grammes. . . . Its surface is of uniform appearance, and "pinkish grey colour." In several parts there are patches of "irregularly rounded form, which occupy a space of half a square "centimètre, and look as if they were produced by the fusing together

* Since the above was printed, Prof. Lebert has published this observation in detail. See Virchow's Archvi, B. XLI. p. 540.

" of the small white patches," of which many are scattered over the surface. " These deposits are stained intensely yellow with bile, while " their sectional surfaces are yellow, smooth, and glistening." The sectional surfaces of the rest of the organ are also smooth. The true " infection nodules," above referred to, show themselves in such sections as new deposits of a pale red colour verging towards grey, in close apposition to each other; so that the bands of redder and more vascular material by which they are separated from each other do not exceed a millimètre in extent. The consistence of the organ is dense, but it is not so dense as a human cirrhotic liver, which in its external form it resembles. Microscopical sections show that here and there there are groups of liver cells in an unaltered state, among which, however, a few contain minute granules of fat. The rest of the organ consists, in great measure, of " a newly-formed tissue, which is of a pale colour, and " clears on the addition of acetic acid. This tissue exhibits innumerable " minute nuclei of various contours, which lie very close to each other. " The tissue is rich in fibres, which run in all directions; and in con- " sequence of its existence the hepatic lobules in many parts are reduced " in size and atrophied."

Of the alterations in the spleen, Professor Lebert gives no detailed description. In suppurated lymphatic glands he found small nodules of cell proliferation, which closely resembled those found in other organs. The nodules were entirely free from suppuration. More generally the lesion consisted in simple hyperplastic infiltration. Next to the lungs and liver, the lymph glands were the organs most frequently infected.

The inaugural thesis, already quoted, of Dr. Roustan, contains many important and interesting anatomical observations, particularly those relating to the lesions found in the peritonæum in the rabbit, and to the results of his successful inoculation of the dog (see pp. 40 and 48).

Peritonæa. granulations the rabbits.

In one of the rabbits inoculated by Dr. Roustan, which was killed two months after, the existence in the mesentery of grey nodules as large as pin heads, and surrounded by radiating lines of thickening, afforded the only evidence of infection. Each of the smaller of these nodules was found, when examined after hardening in chromic acid, to consist of ovoid nuclear elements; each contained a few fine molecules. The nodules are not distinctly circumscribed, the approximation of the individual corpuscles to each other increasing with their distance from the centre, while many are found separate from the mass in the subserous tissue which surrounds it. Towards the centres of the larger granulations the nuclei are indistinct, being intermixed and obscured by numerous fatty and other molecules.

Tuberculous lesions in the dog.

In the dog the most important results obtained by Dr. Roustan were the following:—The gastro-hepatic omentum was beset with numerous minute granulations, from one to two millimètres in diameter. All of these were found to be in relation with vascular ramifications, each completely surrounding the vessel on which it was situated, just as a bead surrounds the thread on which it is strung. They consisted of rounded or slightly oval nuclei, embedded in a stroma, which was hyaline in the smallest granulations, granular and opaque in the largest. Further, in those parts of the mesentery which appeared healthy, there were " little masses of granulation not visible without the aid of a lens, " which, although they were always found in the course of vessels, " appeared to be altogether independent in their development of the " structural elements of the vascular tissue." On the surface of the liver were numerous granulations, from two to four millimètres in diameter, the structural characters of which were identical with those above described. About a dozen granulations were found in the cortex

of the right kidney, some of which were miliary, others larger and more or less opaque and yellow. Here, as in the rabbit, it was found that the corpuscular growth, constituting the smallest granulations, had its seat and origin in the connective tissue between the convoluted tubes, the epithelium and other structures of which were unaltered. In the lungs two distinct lesions could be made out, viz. (1) subpleural indurations, which, in section, were seen to be due to "abnormal "thickening of the inter-alveolar septa," which in the affected parts appeared to be covered with epithelial cells, closely adherent to each other, so as to form an uninterrupted lining to the air vesicle; and (2) more distinct nodules, which consist partly of "nuclei developed "in the septa, partly of granular epithelium accumulated in the alveolar "cavities."

SECTION 3, THEORIES.

We have seen that the accounts given by different observers of the anatomical results of the inoculation of tubercle are remarkably uniform and consistent with each other. But in the interpretation assigned to them no such uniformity is met with. Nor is this in the least to be wondered at if we take into consideration the complicated nature of the questions involved, the novelty of the facts, and their apparent antagonism to those notions about tubercle, which have been hitherto regarded as the teachings of experience.

M. Villemin; reasons for believing that tuberculosis is a zymotic disease.

In giving an account of these theories the precedence is evidently due to M. Villemin, not merely because his experiments were the earliest, but because he is better known in connexion with the subject, at all events in this country, than any other pathologist. His investigation was not undertaken by chance, but in obedience to a conviction previously existing in his mind that *tubercle is a zymotic disease.* To this conviction he had been led by the following considerations; with reference to which it may be remarked that even if the facts on which they are based were indisputable, their bearing on the question is indirect. (1), Tubercle, like the zymotic diseases, is rarely met with in elevated situations; (2), it is most prevalent in crowded populations and especially in great manufacturing and commercial towns; (3), persons who live in common and are confined in their dwellings, such as prisoners, inmates of monastic institutions, &c., are liable to tubercle, while (4), those who live in the open air or lead a nomadic life are comparatively exempt; (5), the frequency of tubercle is greater among soldiers when in barracks, than in armies in the field; (6), those who live with phthisical individuals "in close and ill ventilated dwellings" are apt to become phthisical; (7), phthisis, unknown to certain savage races before their intercourse with Europeans, is now their most destructive scourge; (8), bovine phthisis prevails most among animals that are confined and overcrowded; (9), the antagonism between phthisis and malaria may be explained on the ground that malarious countries are sparsely inhabited; (10), the contagiousness of phthisis has always been matter of common belief; (11), in its development phthisis resembles several of the zymotic maladies. Thus (a) it resembles typhoid fever so closely that it is often indistinguishable from it, the resemblance extending not only to the phenomena observed during life but to the anatomical lesions, which in both diseases have their principal seat in the lymphatic system. The causes which produce them, and the ages at which individuals are most liable to be attacked, are similar. (b.) The likeness of tubercle to farcy is still more striking. In the latter the essential lesion consists in the development of granulations, anatomically

identical with those of tubercle, which have their seat more frequently in the lungs than in any other internal organ, and in both diseases the lymphatic glands undergo enlargement, induration, and caseous degeneration. The etiological relations of the two are the same, while the symptoms are so much alike that it is scarcely possible to point out any differences excepting such as arise directly from the specific differences of the animals affected.*

From all these considerations Villemin inferred that tubercle is not merely a form of perverted nutrition, but a specific disease, one in its essence, however various in its manifestations, and that its cause must be a specific infective material capable of transmission from the diseased to the healthy body, and endowed with the faculty of multiplying itself therein so as to reproduce all the original phenomena. Of the truth of this inference he regards the inoculation experiments as proof. "Tuberculosis can be compared only to the virulent diseases . . . "How the tuberculous virus engenders tubercle we can no more explain "than we can how the syphilitic virus produces secondary syphilis. "The proof of the existence of this morbid principle consists in the fact "of successful inoculation . . . Every morbid material is a virus "which when introduced into the organism in small quantities, deter-"mines lesions which are constant in their character, and can be "shown to exist after the lapse of a certain time in different and remote "parts of the body in increased quantity," and this definition he holds to be fully applicable to tuberculous matter.†

Mr. Simon's verification.

Mr. Simon, when communicating to the Pathological Society his verification of M. Villemin's experiments, did not offer any theory of the facts, but was careful to state that his "testimony to the genuineness of "the very important pathological discovery which M. Villemin claims "to have made" must be understood to be "subject to such qualifica-"tions as an amended pathological definition of 'tubercle' may hereafter "render necessary.

Professor Lebert's first views.

From Villemin let us turn to the learned and laborious professor of Breslau. In concluding his first paper, Professor Lebert says that his own results and those of Villemin prove that in tuberculosis just as in smallpox, syphilis, and farcy, we have to do not with a simple inflammatory process which spreads *de proche en proche*, but with a special element belonging exclusively to tuberculous disease. This opinion is, however, expressed with great caution, for says Lebert, "the experimental investigation of the subject is as yet scarcely begun." Any modification of the current etiological doctrines of organic diseases should be received "with the utmost reserve and under the control of a criticism as sober as it is severe."‡ In his second paper the author displays still greater unwillingness to dogmatise, so that his opinions have to be gathered from such expressions as are scattered here and there throughout his communications. So far as they relate to the most important aspects of the question, viz., the significance of the lesions and the nature of the process by which they are produced, the following passages show that Lebert's present views are in great measure opposed to those expressed in his earlier paper. As regards the significance of the lesions he admits that the condition of the lung observed in inoculated animals

His more recent conclusions.

* M. Villemin points out, that the fact that the two diseases are antagonistic is no argument against their analogy, any more than the antagonism of vaccination to smallpox would afford ground for denying the close alliance which exists between the latter and cowpox.

† Villemin, loc. cit., p. 589.

‡ Bulletin de l'Acad. de Med., tom. 32, p. 151.

Relation between the tuberculous and the inflammatory processes.

is anatomically identical with that which exists in disseminated chronic pneumonia and in acute tuberculosis, but is entirely unwilling to regard the formation of nodules in the lung or elsewhere as constituting *new growth*, the very nature of which he repudiates in the strongest terms.* In short he finds it altogether impossible either to define what tubercle is or to state what are the limits which separate between it and the products of inflammation, and he regards "the whole doctrine "of tubercle as governed by inflammation, an inflammation of which "the development is the more rapid, the more unfavourable is the con-"dition of nutrition of the whole body, and of the affected tissue in "particular, while its progress is accelerated by the absorption of "pathological products or of materials produced by their decomposition. "The minute granulations which we recognize as tubercle are usually "produced by the transportation and dissemination of the products of "an undoubted primary inflammation, which itself may exhibit all "transitions between small granular nodules and extensive infiltrations, "and they are as much localized in the tissues belonging to the type of "the connective tissue as in the epithelial tissues. True tubercular "granulation is therefore closely allied to the inflammatory processes "from which it has originated, and of which, indeed, it is the product." This appears not only from their development, from the mode of extension of the granulations, and from their relation to surrounding parts, but from the characters of the more diffused cell-proliferations which take place in their neighbourhood.†

Prof. Lebert's explanation of the effects of inoculation.

As regards the mode in which the infection takes place, Lebert considers the influence exerted by inoculation as probably partly chemical, partly mechanical. A purely mechanical stimulus appears to him insufficient to explain the facts; "the existence of a purely chemical one "is not proved, and certainly would be difficult to prove, so that it is "only by exclusion that we can judge how much of the observed effect "ought to be provisionally assigned to chemical stimulation, as being "inexplicable mechanically.‡ He thinks it probable that at the point of inoculation "an infective fluid is formed from the material inoculated "and from the products of inoculation, which, conveyed through the "lymphatic and sanguiferous blood vessels, enters into corpuscular "combinations" (in the blood?) "and so produces stimulation and ob-"struction. The conveyance of material by the lymphatics produces "stimulation and proliferation of cells in the lymphatic glands, mani-"festing itself either in infiltration or granulation. . . . But it is "through the blood vessels that the organism is more thoroughly and "deeply infected. Infective material in a broken down, more or less "emulsive condition, or secondary inflammatory products, are absorbed "by the capillaries. . . . All these elements pass without difficulty "through the venous trunks, and probably undergo corpuscular trans-"formation. . . . Having arrived at the right auricle the carriers "of infection [which Lebert thinks are probably cells newly formed in "the blood] pass into the lungs and for the most part stop up the "capillaries like little emboli. Others, however, go through, and so "find their way to the left side of the heart and the systemic circula-"tion. For the most part they miss the openings of the ascending "arteries . . . so that the greater number pass into the descending

* "Ein jeder fühlt sogleich wohin eine so extravagante Begriffs-Erweiterung und Verwirrung führen würde," loc. cit., p. 564

† The above sentences are rather freely translated, the peculiarities of Prof. Lebert's style being such that a literal rendering would be unintelligible.

‡ Lebert, loc. cit., p. 576.

" aorta, and thence into the cœliac axis, whence it happens that the " liver and spleen are much more frequently infected than the kidneys."

" How then does the infection take place? . . . In all probability " the general laws of cell stimulation and proliferation have much more " to do with it than specific peculiarities of the infective juice; for it " is to be observed that the same cells are stimulated to proliferation by " agents of different nature, and on the other hand that the same agent " stimulates different types of cells; in fact the several cells show no " differences of type excepting such as may be accounted for as different " stages of progressive and retrogressive metamorphosis. Similarly " the products of the disintegration of primary granulation or infiltration " become new centres of infection, the influence of which radiates and " extends to more distant parts, so that the infective material may " increase very considerably in the organism." To explain this secondary process as purely mechanical, Lebert regards as "not unphysio- " logical; but the connection of the secondary-foci with the primary " focus can only be explained by admitting the existence of a special " tendency, perhaps a special element of transmission. But let us " beware," he continues, " of identifying the inflammatory infection " with which we are now occupied with neoplastic or heteroplastic " infections, such as cancer, cancroid, &c."*

In the preceding paragraphs I have endeavoured to bring together Professor Lebert's opinions in such a manner as to render them intelligible. In reading his paper one cannot help regretting that he has allowed his views of the nature of the tuberculous process to be so powerfully influenced by his conviction of its inflammatory nature.† In spite of his determination to refer everything to non-specific tissue stimulation, he is obliged again and again to admit that other influences are at work, but does not seem to see that in yielding so much he yields all. Once allow that the stimulus is chemical as well as mechanical, " specificity " can no longer be excluded; for clearly if the effect is chemical the agent must be a specific substance, a proximate principle, for chemistry does not recognize "tendencies." To admit that there is a "*besonderes Element der Uebertragung*" in the blood, and at the same time to deny specificity implies that he who does so, uses the word in a very peculiar sense.

Views of M. Colin.

M. G. Colin, to whom the communications of M. Villemin to the Academy of Medicine in Paris were referred for a report, admits that the experiments made by him prove that tubercle is a contagious disease, but refuses to entertain his conclusions as to its dependence on a specific virus. He regards the whole process as purely mechanical, attributing the lesions to the reception of morbid products into the lymphatic vessels, not by absorption through their walls, but by the "open mouths of wounded capillaries and lymphatics." The course which the infective material follows may be easily traced, especially when pus is mixed with the tuberculous matter, by the engorgement of the lymphatic vessels and the enlargement of the glands. Its progress is so slow that it is not until several weeks have elapsed that it arrives at its destination in the internal organs, where it assumes the form of little masses (*amas*), evidently regarded by M. Colin as products of local inflammation.

Views of M. Chauffard.

In the discussion of M. Colin's report which took place on the 15th of last October, M. Chauffard, in a speech of great length, compared

* Lebert, loc. cit., p. 578.

† "Für uns dominirt die Entzündung die ganze Lehre der Tuberculose," loc. cit.

the effect of inoculation to the fecundation of one tissue by the contact of elements emanating from another, the fecundated tissue being thereby caused to produce histological elements not resembling its own but those of the fecundating tissue. The proliferation which occurs in the affected organs is due according to M. Chauffard to a stimulation of their structural elements, which is strictly local and altogether independent of any general morbid infection or virus. This local stimulation shows itself more especially in the lymphatic glands, the tissue of which may in fact be regarded as the "matrix destined to be fecundated." It is towards them that the tuberculous matter is conveyed by the lymphatics; "the histological elements of which they consist (lymphatic cells or corpuscles) are so nearly allied to those of tubercular granulations, that most of the German pathologists have regarded them as identical, and have considered tuberculous granulation in general as a heterotopical formation of normal lymphatic elements." Like M. Colin, M. Chauffard regards Villemin's experiments as having no bearing whatever on the specificity of tubercle; but he declines to follow M. Colin in his opinion that tuberculosis is contagious. Willingly admitting that the local disease is in reality tuberculous proliferation, and that the disseminated nodules in the lungs and other organs are tubercles, he denies that "the general affection known under the name of tuberculosis" is really communicated to the inoculated animal.

Views of Dr. Waldenburg.

Dr. Waldenburg holds that the process induced by inoculation consists in the intussusception of finely divided particles, smaller, or at all events not larger than blood corpuscles, and in their being deposited in various organs. These particles becoming lodged in the capillaries of internal organs, finally escape out of the circulation by penetrating the vascular wall, in which escape he thinks it possible that they may be accompanied by colourless blood corpuscles, and thus originate miliary granulations in the neighbourhood of the vessels.* He thus holds a position nearly identical with that of M. Colin, although his views are much more clearly and definitely expressed. He regards them as applicable not only to the results of inoculation, but to the development of human tubercle, and thinks that clinical experience justifies the conclusion that in man as in inoculated animals, miliary tubercle is produced in the tissues of affected organs by the deposit of extremely fine particles previously received into the blood-vessels. At the same time he admits that this mechanical process does not constitute the essence of tuberculosis, for without reference to the facts which show phthisis to be a diathetic disease, its hereditary transmission can scarcely be explained unless it be granted that it consists of something more than anatomical lesions. Like Professor Lebert Dr. Waldenburg expresses himself with great caution, and conceals from himself and from his readers his belief in what other people designate the tubercular diathesis, by speaking of an "hereditary susceptibility to stimulation," and so forth.

Summary.

From the preceding summary of the views entertained by the principal pathologists who have directed their attention to the subject, it will be seen how numerous are the aspects in which the results of tubercle inoculation may be regarded, and how complicated are the questions which arise out of them. It is important, however, to notice that in so great a diversity of opinion there are certain particulars in respect of which all are agreed. Thus it is generally admitted that the certain result of the inoculation of tuberculous matter of whatever kind is to produce crops

* Dr. Waldenburg considers that the researches of Cohnheim have demonstrated the possibility of the escape of blood corpuscles from the capillaries, independently of rupture.

of miliary granulations in the lungs and other internal organs; that these granulations are anatomically identical with grey tubercle, that they become yellow and opaque, and eventually break down into a soft cheesy material. It is further admitted on all hands that the process is, so to speak, a self-diffusive one, that in the act of inoculation a new element is introduced into the inoculated animal at the point of insertion, from which it is disseminated to all parts of the body through the lymphatic and arterial circulation.

At this point agreement ceases. It is neither agreed what the new element is, nor what is the nature of its effect on the blood, or on the living tissues to which the blood-stream carries it. With reference to these questions we find three views indicated. They may be expressed as follows: (1.) The material introduced consists of microscopical particles, possessed of no properties excepting those they owe to their hardness, form, and magnitude, and therefore capable of producing no effects excepting those of mechanical irritation. (2.) The material consists of living matter, capable either of growth by assimilation of new matter similar to itself, or of causing morbid transformations in the tissues with which it comes into contact; in either case acting in a specific way which cannot be referred to its physical properties. (3.) It is a definite chemical compound which is soluble in the blood plasma, and has a special and exclusive action on certain tissues, particularly that of the lymphatic glands and other analogous structures.

Practically, the first and second of these propositions are the only important ones; for, although Professor Lebert has suggested the co-operation of a chemical with a mechanical action, he has given no explanation of his meaning. That it is possible to conceive of such an agent as is described in the third proposition can scarcely be disputed, but the extremely small quantity of the material used, taken together with the postponement and protracted duration of the results, are facts of which no intelligible chemical explanation can be given, so that the issue may be narrowed, so far as relates to the origin of the morbid process, within the limits indicated in propositions 1 and 2. If, on the one hand, the lesions can be fully accounted for by the entrance of minute particles of hard, but absolutely insoluble and innocuous material into the arterial circulation, we are bound to accept this explanation as the simplest, and to admit with Prof. Lebert that the granulations are merely circumscribed inflammations. If, on the other hand, none of the effects can be explained on this mechanical principle, little seems to be left to us but to admit that the contagium of tubercle acts in the same way as the contagia of the so-called specific diseases. Lastly, if the distribution of the granulations and their similarity to those produced mechanically, should seem to suggest that their mode of origin may be mechanical, while other influences manifest themselves in their development, we are perfectly at liberty to adopt the mechanical explanation, so far as it goes, and to supplement it with such other explanations as the facts may warrant.

APPENDIX.

No. 6.
On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.

POSTSCRIPT.—(March 31.)—Observations which I have had the opportunity of completing since this report was in type, afford evidence of so important a character in support of some of the conclusions embodied in it, that I gladly avail myself of the opportunity which has been afforded me of adding the results.

It has been found that if animals are inoculated with pus derived from the secondary abscesses of patients affected with pyæmia, death is apt to occur during the third or fourth week after inoculation, in which case the results of dissection is as follows :—Abscesses are found at the seat of inoculation, and purulent deposits in the neighbouring subcutaneous tissue ; these, although obviously of the same character as those observed after inoculation of tubercle, differ from them in being larger, more numerous, and more generally distributed. The subcutaneuos lymphatic glands are healthy, or at most a little enlarged. The internal organs are usually free from disease. When this is not the case, lesions of an obviously inflammatory nature are found; as for example, pleuropneumonia, pericarditis, or subpleural or subperitoneal abscesses. If, on the other hand, the animals survive the primary, *i.e.* hyæmic, effects of which these lesions are the expression, and are examined several months after inoculation, morbid appearances are found in the lungs, liver and spleen, in which all the anatomical pcaracters of a tuberculous process are to be recognized.

From these facts it is evident that these lesions can no longer be regarded as dependent on any property or action possessed by the inoculated material in virtue of its having been taken from the diseased organs of a phthisical patient. This conclusion is rendered almost certain by the result of the following experiment. On the 29th of October last, setons of unbleached cotton were inserted, by means of a needle which had not been used before, in the shoulders of two guinea-pigs, which from their being entirely white could be easily distinguished from any of the other animals under observation, all of which happened to have spots of colour. One of these animals was killed on the 28th of December, and was dissected by Mr. Simon and myself. One of the setons was surrounded by a hard mass of semi-transparent substance—obviously ~~dried-up pus,~~ which was surrounded by connective-tissue induration. The other abscess was of considerable size ; the material contained in it was of the consistence of cream cheese, and on microscopical examination the corpuscles of which it consisted were found to have the characters represented in Plate I., fig. 9 (see description). The internal organs were perfectly healthy. The other animal died on the 15th of March. There were two open wounds on the left shoulder, each of which led to a sinuous cavity, containing a small quantity of pus, the greater part of the contents of the abscesses having escaped externally. Both cavities were connected with each other and with the neighbouring scapular gland, which was enlarged and softened, by subcutaneous bands of induration, and there were numerous purulent deposits in the neighbouring muscles and areolar tissue. The lungs contained very numerous iron-grey nodules. The liver was much enlarged, and presented the characteristic appearances of interstitial adenoid deposit. In the spleen there were numerous miliary nodules. There was enlargement of the agminate glands both of the large and small intestines, as well as of the lymphatic glands in the gastrohepatic omentum and mesentery. In this case, therefore, a pathological process which had originated in traumatic subcutaneous suppuration resulted in lesions which were characteristically tuberculous.

PLATE I.

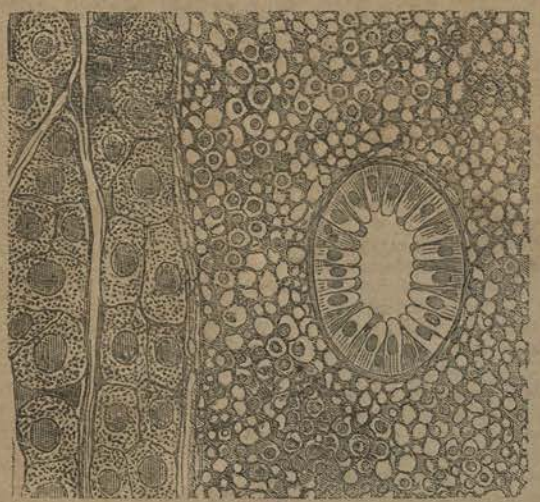

Fig. 1.

Fig. 2.

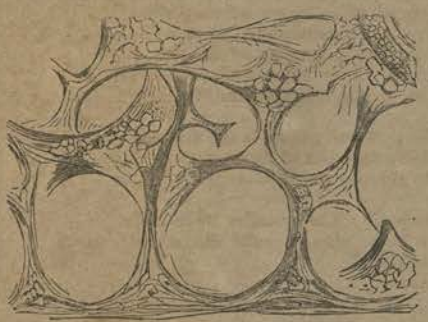

Fig. 3.

Fig. 4.

Fig. 5.

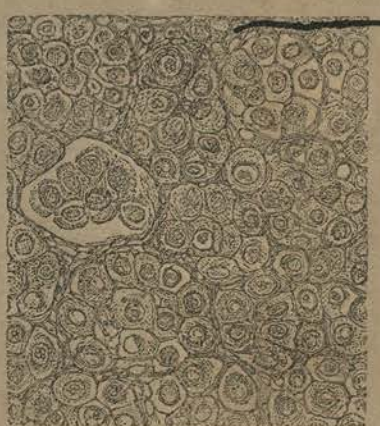

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

EXPLANATION OF THE PLATE.

FIG. 1.—Section of diseased tissue of the liver. In the middle of the drawing is seen a bile-duct lined with epithelium, about $\frac{1}{400}$ inch in diameter, which is cut across obliquely. The duct is surrounded by adenoid tissue, the nuclei of which appear to be contained in the cavities of a transparent loculous stroma. To the left this tissue is separated by a well defined border from the liver cells, which are arranged in oblong masses, between which there are capillary blood vessels.

FIG. 2.—Section of a superficial miliary nodule in the spleen. The natural surface is cut through vertically. Towards the upper part of the drawing, where the tissue is nearly healthy, the nuclei are larger, and many of them look as if enclosed in cells. Near the surface they are smaller and more numerous, so that the loculi appear to be choked with them. This multiplication seems to constitute the only difference between diseased and healthy parts.

FIG. 3.—Section of healthy lung; the pleural surface is cut across vertically.

FIG. 4.—Vertical section of the wall of a minute subcutaneous abscess. Nearest the cavity of the abscess its wall is seen to consist of closely packed corpuscles, some of which, larger than the rest, resemble pus-corpuscles. At a short distance from the surface the corpuscles are arranged in oblong heaps, which lie in a faintly fibrillated stroma. Still further there are numerous staff-shaped nuclei, not distinguishable from those of the surrounding indurated connective tissue.

FIG. 5.—Peribronchial granulation of lung. At the lower part of the drawing is seen a bronchial tube cut across. It is surrounded on all sides by an accumulation of spheroidal corpuscles, which constitute the kernel of the granulation. The walls of the neighbouring alveoli are thickened. Above is seen a portion of an artery (dislocated in the section, so that it lies on its side), and to the left another artery, which is much smaller. Each is surrounded by its adventitia, the structure of which appears to be unaltered.

FIG 6.—Section of iron-grey induration of lung. The pleural surface is cut through vertically. The alveolar cavities are completely filled with nests of large nucleated cells, most of which contain pigment granules. The alveolar tissue is only slightly altered.

FIG. 7.—Creamy pus from a subcutaneous abscess. The smaller spherical corpuscles resemble those of normal human pus. The larger ones have the characters of glomeruli, and are scarcely affected by dilute acetic acid.

FIG. 8.—Action of acetic acid on the smaller corpuscles.

FIG. 9.—Pus-corpuscles from a caseous abscess. When acted on by acetic acid, their outline becomes more defined, but their appearance is otherwise unaltered.

FIG. 10.—Cretaceous granules from nodules in the spleen.

TABLE OF MEASUREMENTS.

	Diameters.
Subcutaneous tissue:	
Spheroidal nuclei of indurated connective tissue -	$\frac{1}{4100}$ — $\frac{1}{3500}$ inch.
Spheroidal corpuscles of pyogenic membrane (see Fig. 4)	$\frac{1}{2800}$
Pus corpuscles (see Fig. 7) - - - -	$\frac{1}{2000}$
Glomeruli - - - - - -	$\frac{1}{1000}$
Lungs:	
Spherical corpuscles of granulations (see Fig. 5) -	$\frac{1}{4400}$ — $\frac{1}{3300}$
Nuclei of inter-alveolar thickening, about - -	$\frac{1}{2800}$
Nuclei of intra-alveolar cells (Fig. 6) - -	$\frac{1}{2500}$ — $\frac{1}{2000}$
Intra-alveolar cells - - - -	$\frac{1}{1400}$ — $\frac{1}{1000}$
Liver:	
Nuclei of adenoid growth - - - -	$\frac{1}{5500}$ — $\frac{1}{4500}$
Nuclei of liver-cells - - - -	$\frac{1}{3000}$ — $\frac{1}{2400}$
Spleen:	
Nuclei near surface in section represented in Fig. 2.	$\frac{1}{4100}$ — $\frac{1}{3500}$
Nuclei further from surface in the same section -	$\frac{1}{2800}$ — $\frac{1}{2400}$
Peritonæum:	
Nuclei, mostly oval, constituting perivascular granulations in omentum - - - -	$\frac{1}{2800}$ — $\frac{1}{2500}$
Occasionally much larger nuclei are seen, not less than	$\frac{1}{1800}$

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

No. 7.—DR. THUDICHUM'S REPORT (chiefly introductory) on RESEARCHES intended to promote an improved CHEMICAL IDENTIFICATION of DISEASES.

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I.—RELATIONS OF THE SUBJECT TO GENERAL CHEMISTRY.

Objects of researches.

The broad object of the researches to be reported on in the following pages is to advance the knowledge of disease by such new chemical information as may be established with certainty. Mere quantity of result is regarded as of secondary importance; and if, nevertheless, the researches should appear to spread over a very large area, it must be remembered that none claim to be considered complete which are not expressly put forth as such. And the method upon which all the researches are conducted is to be judged only from the finished portions; it being implied that a similar completion is to be given in the future to subjects appearing at present only in outline. Of finished portions, the essays "on cholophæine," "on biliverdine," and "on uromelanine," may be quoted, of which abstracts will presently be given, and which were presented *in extenso* to the Royal Society by the Medical Officer. The whole of my method may further be seen, applied hurriedly, owing to the rapidity of the epidemic and external difficulties, in the "Chemical Researches on Cholera," published in the annual report of the Medical Officer for 1867.

Difficulty of separating physiol. and pathol. research.

It has been found impossible to exclude physiological research, although the final aim is pathological information. The chemist in general mainly cares for isolation and characterisation of *well-defined substances*. Having in a research found enough of these to reward his intention, he would generally neglect the residues. Owing to this practice, quite natural on the part of chemists, a great part of the constituents of the body is at present unknown, or imperfectly known. Thus the brain yields cerebric acid, but contains also a large bulk of a peculiar compound, which if able to yield cerebric acid, is a complicated compound of this matter with other unknown substances. This peculiar compound is neglected by all chemists who have ever made inquiries on the brain; the pathological chemist is, however, called upon to deal with it, as he cannot form any conception of pathological processes of the brain matter before knowing the chemical constitution of the

whole. Again, of the watery extract of muscles only one-sixth is defined, five-sixths are undefined. It would be impossible to judge of muscular affections, be they direct and local, or indirect and effected by nerve-lesions, without a knowledge of these at present undefined matters. They have therefore to be studied, as chemists in search merely of defined bodies would not turn their attention to ungrateful, difficult, and expensive researches.

Difficult objects of physiol. research.

Physiological chemistry experiences its main difficulty in the changeable nature of its objects. Latterly another has been added to our knowledge which is almost stupendous in character. It is the extremely high atomic weight of the main ingredients of the body; a weight, which in the red-coloured ingredient of the blood rises to 13,000, and in the brain probably much higher. Ordinary organic chemistry deals with comparatively simple substances, in which the atomic weights do not exceed as many tens as in the physiological molecules before mentioned there are thousands. The fact that synthetic chemists can imitate some simple organic compounds must, when these immensely complex molecules are remembered, cease to be matter for very great boast. And the same knowledge has had a corrective influence upon a much more important part of our philosophy. We believed that the plant only was synthetical, that the animal merely applied what the plant had previously prepared. This however is not the case. True, in seeds there is even cerebric acid (or some body very much like it) as well as in yelks and brains. But in neither there is brain-matter. In yelks there is the capability for the production of blood, but not blood itself; in seeds there is no blood, and no capability for forming it; hematocrystalline is the product of the synthetical activity of the animal economy. Both plants and animals, therefore, are chemically constructive, but the animals build with the materials previously prepared by plants; plants construct from inorganic food, animals from the organic food offered by plants or other animals; and the molecules which animals construct surpass in complication and number of atoms any which plants produce.

Intricacy of problems of pathological chemistry.

Far more intricate is the problem of pathological chemistry. It deals with the deviations of these substances which are infinitely complicated, one penetrating the other. It deals with processes which (so far as we know them) are ever tending to become normal, and which (if they do not kill) terminate in definite times. The objects of the research occur for the most part only accidentally, fitfully, with all sorts of admixture, and not at such times and places so as to favour investigation. If physiology seeks a definition of life, pathology is held to aid in this search and the search after the nature of disease at the same time. And if it were only an inquiry after the destructive nature of disease it might appear simple; but the problem has a physiology of its own, it is synthetical as well as life, for morbid growths must be considered syntheses.

Disease obeys natural laws.

The processes and products of disease obey the same general natural laws as all other processes and matters, and in addition the laws of their special causation. Carbon in the smallpox-pustule remains carbon, and subject to the laws under which that element exhibits its various properties; but it deviates in function for a while by the agency of a special interfering cause. In the case of small-pox this cause is probably physical, but in other diseases, such as paralysis from terror, cannot be so. In a complete system of etiology all manner of causes have to be considered; but in pathological chemistry, only such causes as are chemical. Therewith all chemical effects from any causes whatever, come under consideration.

Definition of pathological chemistry.

I define pathological chemistry as the science of the deviation of atoms

from their normal function. Ultimate pathology cannot, I think, be cellular, as was claimed by Virchow, or molecular, as was at one time taught by Hughes Bennett and Beale, but can only be atomic; and if a further subdivision of matter in power and place going beyond the atom should become possible, then pathology must still be atomic before it can be considered by the light of the more expanded theory.

Although the definitions of the chemical terms used in pathological chemistry do not differ from those used in general chemistry (as far as the subjects are identical), yet it may be useful in this place to shortly summarise these terms and definitions, as they occur repeatedly in the sequel. Moreover, there have lately been changes in and additions to the doctrines concerning atoms and their symbols, and relative weights, and powers; and these it is well to state, in order to avoid the confusion which their use without explanation might cause even to persons well versed in the chemistry of the equivalential period.

Element.

We define "element" as matter which appears to be chemically homogeneous, *i.e.*, which by no chemical means can be separated into two chemically heterogeneous matters. The idea of element therefore precedes that of atom, and the idea of atom in the chemical sense can only exist after the admission of the definition of element. An "atom" is the smallest quantity of an element which can exist in any chemical combination. And further, it can exist only in combination, and not by itself in the free state. The atom has powers which must be satisfied, and if it is prevented from existing in combination with heterogeneous elements, it combines with at least one atom of its own kind or element differing from it only in quality (polarity) of power. Such a combination of two atoms is the type of a molecule, and the smallest possible molecule. A molecule can exist by itself or react upon others. It may consist of two atoms or any number of atoms (up to 1,895, see blood) and the limits up to which the number of atoms in molecules may increase are at present unknown. "Molecule" we define as the smallest quantity of an element or compound which may exist in the free state or enter or leave a combination.

Atom.

Molecule.

Chemism.
Polarity.

All atoms possess chemism, polarity, and dynamicity. "Chemism" is the liability, or the cause of the liability of matter to undergo interchange, movement or combination, and to transform into chemical movement such physical influences as those of sunlight. "Polarity" on the other hand determines the relative place of each atom in the forthcoming combination, and thus fixes the molecule. Let us assume the existence in a molecule of hydrogen of two atoms of hydrogen, having, the one + or positive, the other negative or —, polarity. This plus and minus is to signify that the polarities are heterogeneous, and capable of neutralising each other by combination. Let us express the molecule of hydrogen by the formula $\overset{+}{H}\ \overset{-}{H}$. If now to this molecule we bring a molecule of another element possessing the necessary chemism, *e.g.*, chlorine, and similar polarities of atoms, $\overset{+}{Cl}\ \overset{-}{Cl}$, then a combination by interchange will take place, and two molecules, having equal elements, of hydrochloric acid, namely $\overset{+}{H}\ \overset{-}{Cl}$ and $\overset{-}{H}\ \overset{+}{Cl}$, will be produced; but these molecules will have unequal properties in as far as the polarity of their elements is concerned; for the one will have plus or positive hydrogen $\overset{+}{H}$ and negative chlorine $\overset{-}{Cl}$, while the other will have negative hydrogen $\overset{-}{H}$ and positive chlorine $\overset{+}{Cl}$. However slightly these differences may affect the ultimate products in their grosser properties, they are real and have to be borne in mind in all higher chemical

considerations.*] The "dynamicity" of a given atom is the varying quantity of its combining-power under varying conditions :—for instance, the atom of iodine is monodynamic in hydriodic acid, where it combines with a single atom of monodynamic hydrogen ; tridynamic in terchloride of iodine, where it combines with three monodynamic atoms of chlorine. The "dynamis" is exerciseable in multiple directions, but not separable as to seat. The unit or minimum of dynamis manifested by an atom is a "monad." The maximum dynamis which can be manifested by an atom is atomic power, and as this is ascertained by relative weight it is termed "atomic weight." The quantities expressing the atomic weights have been derived from the circumstance that elements combine in certain proportions of unchangeable weights, or of simple multiples of those weights, and that these weights stand in a certain proportion to the volume which bodies (which are capable of existing as gases) maintain in their gaseous condition. An atom of hydrogen occupies one volume, a molecule occupies two. An atom of chlorine occupies one volume, a molecule two. The atom or volume of hydrogen is much lighter than the atom or volume of chlorine, weighing 1, while the latter weighs 35·5. By the combination of these two molecules two fresh molecules of hydrochloric acid are produced. These occupy the same volume as the uncombined gases previously did. The definition of molecule as two volumes of a compound of a gaseous body leads to the knowledge of the condensation which elements have undergone during the process of combination, and by all other considerations of the properties of atoms, and of the specific heats of elements, to the knowledge of the atomic weights. These as lately determined differ from the former equivalents by the fact that many have been doubled. They are distinguished in their symbols by a horizontal bar, thus $\cancel{C}$, standing across the middle of the letter. As many of these symbols have to be used in the sequel, I here give a list of them, together with the dynamicities and atomic weights of the elements.

Dynamicity.

Monad.

Atomic weight.

Names.	Symbols.	Dynamicities.	Atom. weights.
Aluminium - - -	$\cancel{Al}$	III. VI.	27·5
Antimony - - -	Sb	III. V.	122·
Arsenic - - - -	As	III. V.	75·
Barium - - - -	$\cancel{Ba}$	II.	137·
Beryllium - - -	Be	III.	14·
Bismuth - - -	Bi	III.	208·
Boron - - - -	Bo	III.	11·
Bromine - - -	Br	I.	80·
Cadmium - - -	$\cancel{Cd}$	II.	112·
Caesium - - -	Cs	I.	133·
Calcium - - -	$\cancel{Ca}$	II.	40·
Carbon - - - -	$\cancel{C}$	IV.	12·
Cerium - - - -	$\cancel{Ce}$	II.	92·

* The lactic acid of milk differs from the lactic acid of flesh, not in composition but unimportant collateral properties. There are several turpentines distinguishable only by different influence on the polarised ray of light. These may possibly differ from each other only by some such peculiar disposition of subordinate power (polarity) as is illustrated in the above example.

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

Names.	Symbols.	Dynamicity.	Atom. weights.
Chlorine	Cl	I.	35·5
Chromium	Cr	III. VI.	52·5
Cobalt	Co	II.	58·8
Copper	Cu	II.	63·5
Didymium	Di	II.	96·
Erbium	Er	II.	112·6
Fluorine	Fl	I.	19·
Glucinum	G	II.	9·
Gold	Au	III.	196·7
Hydrogen	H	I.	1·
Iodine	I	I. III.	127·
Iridium	Ir	II. IV.	198·
Iron	Fe	II. VI.	56·
Lanthanium	La	II.	92·
Lead	Pb	II. IV.	207·
Lithium	Li	I.	7·
Magnesium	Mg	II.	24·
Manganese	Mn	II. VI.	55·
Mercury	Hg	II.	200·
Molybdenum	Mo	VI.	92·
Nickel	Ni	II.	58·8
Niobium	Nb	IV.	97·6
Nitrogen	N	I. II. III. V.	14·
Osmium	Os	IV.	199·
Oxygen	O	II.	16·
Palladium	Pd	II.	106·5
Phosphorus	P	III. V.	31·
Platinum	Pt	II. IV.	197·4
Potassium	K	I.	39·
Rhodium	Rh	II.	104·
Rubidium	Rb	I.	85·5
Ruthenium	Ru	IV.	104·
Selenium	Se	II.	79·
Silicium	Si	IV.	28·5
Silver	Ag	I.	108·
Sodium	Na	I.	23·
Strontium	Sr	II.	87·5
Sulphur	S	II.	32·
Tantalum	Ta	IV.	137·5
Tellurium	Te	II.	128·
Thallium	Tl	I.	204·
Thorium	Th	IV.	231·3

Names.	Symbols.	Dynamicities.	Atom. weights.
Tin - - - -	Sn	IV.	118·
Titanium - - - -	Ti	IV.	50·
Tungsten - - -	W	VI.	184·
Uranium - - -	U	II. III. VI.	120·
Vanadium - - -	V	II. V.	51·2
Yttrium - - -	Y	II.	68·
Zinc - - - -	Zn	II.	65·
Zirconium - - -	Zr	IV.	90·

The foregoing system is in harmony with all other facts, chemical or physical, concerning elements, because the atomic weights are, with three exceptions,* the same as those derived from the law of Dulong and Petit, which is to the effect that the specific heats of elements multiplied by their atomic weights give the same product. If we term this product "atomic heat," we may say that these elements possess the same atomic heat. Further, the atomic heats of a great number of compounds are equal to the sums of the atomic heats of their elements. A second great reason for the adoption of the new atomic weights is, that they are in harmony with the law of isomorphism (Mitscherlich); and a third, that they are in harmony with the relations existing between the density of the gases and vapours and their molecular weights: that is to say, the densities of the simple gases stand in the same proportion to each other as their atomic weights, or, hydrogen being accepted as the unit or = 1, the figures expressing the densities of the other gases compared to hydrogen as 1, are the same as those expressing their atomic weights (Gay-Lussac). This led to the law of Ampère and Berzelius, according to which equal volumes of simple gas contain equal numbers of atoms †; and to the further development of that law that equal volumes of gas contain equal numbers of molecules, and, consequently, that the molecular weights of compounds are proportioned to their densities in the state of vapour or gas.

Atomic heat.

Of the compounds of simple gases several undergo condensation, others do not. Thus two vols. of hydrogen and one vol. of oxygen, when combined, form two volumes of water vapour; one vol. of nitrogen and three vols. of hydrogen form two vols. of ammonia gas; one vol. of carbon and four volumes of hydrogen form two volumes of marsh gas. From this it evident that the greater the number of atoms contained in a molecule, the greater must be the condensation of the elements. An idea may be formed of the possible amount of this condensation by the consideration that a molecule of water vapour containing three atoms fills two volumes, while the same two volumes would be filled by a molecule of hematocrystalline containing 1,895 atoms, could this substance be brought into the gaseous state.

Condensation.

The development of all vegetable and animal matters is effected by progressive condensation. This may be proved to be correct by the synthetical method. Elements are brought in immediate contact, and

Synthetical method.

* Silicium, carbon, and boron.

† To this phosphorus, so common in the animal economy, and arsenic, form exceptions, being both too dense for satisfying that law, and cadmium and mercury form the exception on the opposite side, being both too expanded.

influenced by the application of forces which have the power to produce chemical movement; such forces are electricity, heat, light, or their conversions, such as pressure and concussion. Electricity may break up molecules and form them, and the formation of one set of molecules implies the breaking up of others; but not one or other, but all available synthetical powers are required to build up even simple substances in the laboratory. First elements are combined, then the combinations are condensed, then they are brought in contact with others and combined and simultaneously condensed, then additions are made, and when the dynamicities of all atoms are saturated, substitutions are effected. These processes lead to the knowledge of functional types, which might metaphorically be termed "organs of the chemical idea," or of chemism. These types are the following :—

Functional types.

1. Hydrocarbon (example, marsh gas), $\mathfrak{C}\,H_4$.
2. Alcohol (methylic alcohol), $\mathfrak{C}\,H_4\,\mathfrak{O}$.
3. Acid (formic acid), $\mathfrak{C}\,H_2\,\mathfrak{O}_2$.
4. Aldehyde (ordinary aldehyde), $\mathfrak{C}_2\,H_4\,\mathfrak{O}$.
5. Ether (methyl-formic ether), $\mathfrak{C}\,H_2\,\mathfrak{O}_2+\mathfrak{C}\,H_4\,\mathfrak{O}—H_2\,\mathfrak{O}$.
6. Alcali (methylamine), $\mathfrak{C}\,H_5\,N$.
7. Compound metallic radical (arseno-methyle), $\mathfrak{C}\,H_5\,As$.
8. Amide (formic amide), $\mathfrak{C}\,H_3\,N\,\mathfrak{O}$.

Structural types.

But with those functional types must not be confounded the structural types, which result from successive condensation of the type molecule hydrogen, HH, H_2H_2, H_3H_3, H_4H_4, H_5H_5, H_6H_6, &c., and substitution of one or several atoms by an equal number of dynamic monads. Thus by substitution of H_2 in the second type by a didynamic atom (equal to two monads) of oxygen, $\mathfrak{O}^{II}$ (the roman numeral indicates the dynamicity as in the third column of the list of elements above given), water $\mathfrak{O}^{II}H_2$ is produced. When in the third type H_3H_3; one factor is replaced by a tridynamic atom of nitrogen N^{III}, ammonia $N^{III}\,H_3$ results. From the fourth type results marsh gas $^{IV}H_4$ in a similar manner. From the fifth by substitution of one factor by a pentadynamic atom of phosphorus P^{V}, and of the second factor by five atoms of chlorine, Cl_5, the type perchloride, results, and so forth to an extent as yet unexplored. These types hydride (oxyde or acid or) water, ammonia, hydrocarbon, and perchloride may also inversely be derived from the dynamicity of the elements above supposed to be substituted, each monad being satisfied by the attachment of an atom of hydrogen. The theory of types served as a basis of classification and an instrument of discovery in the hand of its excogitator, Gerhardt. For similar purposes it has constantly been used in the following researches.

From the ideas of element, atom, molecule, condensation, and substitution, all types, all series, all chemical compounds derive; all chemistry has the chemistry of hydrogen for its type and unit.

II.—SKETCH OF CHEMICAL PHYSIOLOGY, AND OF ITS POINTS OF CONTACT WITH PATHOLOGY.

Digestion.

The food of man, variously prepared by mechanical processes and chemical operations (cooking), is comminuted in the mouth by chewing. At the same time it is mixed with a variety of fluids, some of which have chemical powers and predispose the food to a change, while others

serve mechanical objects only. The mixture of these fluids is termed saliva; but however homogeneous may appear that mixture, the properties of its components are very various. For the secretion of every particular kind of glands, of which there are four, differs, and the secretion of one and the same gland or set of glands may vary according to the agencies which call them into action. Underneath the forepart of the tongue is secreted from one and the same duct the saliva of a gland which lies under the tongue (sublingual), and that of two other glands which lie farther back on both sides of the tongue underneath the lower jaw (submaxillary glands). To collect either of these secretions little tubes have to be carefully introduced into the respective ducts, which is a matter of some difficulty. For this reason the chemical composition of the secretions of the separate glands is very imperfectly known. Experiments upon animals have shown that these glands can give four different kinds of secretion, according to the nerves which are irritated for the purpose. One nerve, a branch of the facial, and a continuation of the chord of the tympanum, on irritation causes a clear, slightly ropy secretion from the submaxillary glands. This "chordal" saliva contains about 4 per cent. of solid matters, of which 1·5 are globuline, mucine, and coagulable albumen; 2·5 per cent. are mineral, mainly alkaline chlorides and lime-salts; of these latter the carbonate, dissolved in excess of carbonic acid, frequently decomposes in the mouth, and deposits crusts of lime carbonate upon the teeth, which are popularly called tartar. On irritation of the sympathetic nerve the submaxillary glands secrete an opaque very tough saliva. This contains from 15 to 28 per mille of solids, amongst which is mucine, and granules or roundish lumps of an albuminous matter, and much free alkali. The third kind of saliva is that which flows when the submaxillary ganglion is made the centre of a reflex action which works by way of the lingual nerve. This is the only secretory act without the intervention of cerebrospinal influence that is known at present. The fourth kind of saliva is the "paralytic," or thin watery fluid which is secreted under the influence of nervous paralysis, caused either by degeneration, or poisoning, or wounds which separate the secretory nerves. Its composition is not yet ascertained.

Saliva.

Chordal saliva.

Sympathetic saliva.

Ganglionic saliva.

Paralytic saliva.

The mixture of sublingual and submaxillary saliva in man (not in animals) contains rhodanate or sulphocyanate (also termed rhodanide or sulphocyanide) of potassium and sodium $\mathfrak{C}$ N K $\mathfrak{S}$, and $\mathfrak{C}$ N Na $\mathfrak{S}$, recognized by the red colour which iron-chloride imparts to saliva, or to the distillate obtained from it with acids. In another part I draw attention to a similar reaction of urine, which differs however from that of saliva in this, that the body producing it is not volatile. These phenomena admit at present of no particular theory.

Rhodanates in saliva.

The saliva which is secreted by the parotid glands can easily be collected by the introduction of canulæ into the ducts. It is an alkaline, hardly viscous fluid, which contains a little albumen, some globuline, a particular ferment termed ptyaline, but no mucine. It contains much rhodanate, and is the most suitable material for preparing the distillate of rhodanic acid. It contains, water 995·3; solids 4·7; of these are organic 1·4; mineral 3·3; of the latter there is lime carbonate 1·2. The parotid saliva transforms starch into sugar by means of the ferment termed ptyaline. This is the only agent in saliva which has that power. It can be isolated by adding phosphoric acid and subsequently lime to saliva. Ptyaline adheres to the phosphate, is washed out by water, and precipitated by alcohol. It contains nitrogen but is not albuminous, refusing to yield the xanthoproteic acid reaction with nitric acid. The diastase of malt has a similar action used in

Parotid saliva.

Ptyaline.

Glycogeny.

Diastase Liebig's food.

trade fermentations. An interesting and important application has lately been made of diastase by Baron Liebig, for the production of a food for infants, and it is probable that the alkaline mixture supplies efficiently the want of alkali and ptyaline in the digestive juices of children who are being brought up without mother's milk, or with such as is not in a healthy state. Diastase acts best at 66°, while ptyaline is destroyed at 60°. An agent similar to ptyaline is emulsine, or synaptase of almonds, which has been recommended as a dietetic remedy in diabetes. But it does not seem to affect starch in any way, although decomposing amygdaline and salicine.

Emulsine or synaptase.

$$\overbrace{\mathrm{C}_{20}\mathrm{H}_{27}\mathrm{N}\mathrm{O}_{11}}^{\text{Amygdaline.}} + \overbrace{2\,\mathrm{H}_2\mathrm{O}}^{\text{Water.}} = \overbrace{\mathrm{C}_7\mathrm{H}_6\mathrm{O}}^{\text{Oil of bitter almonds.}} + \overbrace{\mathrm{C}\mathrm{H}\mathrm{N}}^{\text{Prussic acid.}} + \overbrace{\mathrm{C}_6\mathrm{H}_{12}\mathrm{O}_6}^{\text{Sugar.}}$$

$$\overbrace{\mathrm{C}_{13}\mathrm{H}_{18}\mathrm{O}_7}^{\text{Salicine.}} + \overbrace{\mathrm{H}_2\mathrm{O}}^{\text{Water.}} = \overbrace{\mathrm{C}_7\mathrm{H}_8\mathrm{O}_2}^{\text{Saligenine.}} + \overbrace{\mathrm{C}_6\mathrm{H}_{12}\mathrm{O}_6}^{\text{Sugar.}}$$

In these transformations sugar is a collateral product, while in that of starch by ptyaline or diastase it is the only product.

Starch.

Starch consists of two bodies, which in the little granules are disposed in alternating layers. The first is granulose, and has the property of being coloured blue at once by free iodine. The second is cellulose, not coloured blue by iodine at once, but only after sulphuric acid or zinc-chloride has been allowed to act upon it. When unboiled starch is mixed and digested with saliva for days, the granulose is dissolved out of the corpuscles and transformed into dextrine and sugar, and the cellulose only is left. At higher temperatures this also is changed. Boiled starch is more easily transformed, as the granules are burst and admit the altering juices between their layers with facility. The first symptom of the addition of saliva to boiled and cooled (to 40° C) starch or pap is increased fluidity, indicating the formation of soluble starch and dextrine. At a later period only sugar is formed, according to the following formulæ :—

Starch (synonym=amylon.) . . . $\mathrm{C}_6\mathrm{H}_{10}\mathrm{O}_5$
Soluble starch . . . } The same formula as starch.
Dextrine . . . . }

$$\overbrace{\mathrm{C}_6\mathrm{H}_{10}\mathrm{O}_5}^{\text{Dextrine.}} + \overbrace{\mathrm{H}_2\mathrm{O}}^{\text{Water.}} = \overbrace{\mathrm{C}_6\mathrm{H}_{12}\mathrm{O}_6}^{\text{Sugar.}}$$

Amyloid degeneration.

Amongst the products of degeneration of the spinal marrow in locomotor ataxia, there are bodies resembling starch corpuscles, but consisting entirely of cellulose.

I had an opportunity afforded me of examining such a case, in which the sense which in physiology we now term the sense of pressure was almost entirely lost, while the sense of pain and the sense of heat and cold persisted. On examining microscopically, and by means of sulphuric acid and iodine, thin sections of the spinal marrow, I found in various parts of it agglomerations of blue bodies imitating in a remarkable manner wheat-starch coloured blue by iodine. The term *amyloid* is perfectly correct as applied to this particular degeneration. The reaction of these bodies, however like to that of amylum, is not that of amylum itself, for amylum is coloured blue by iodine alone, while these bodies require the concurrence of sulphuric acid and iodine.

Mixed saliva.

The secretion of the salivary glands mixed with the mucus of the membranes of the cavity of the mouth, secreted by little follicles,

constitutes mixed saliva. This can be collected in quantity by irritating the fauces with a feather, and producing vomituritions. It does not reduce alkaline copper solution, but retains a little copper oxyde in solution when copper salt and alkali only are added. It transforms starch into sugar, so that chewed pap after some standing, with copper sulphate and caustic potash, at 70° C, yields red copper suboxyde. It does not change cane-sugar into invert sugar, and thus differs from yeast. The quantity of mixed saliva secreted by a man in 24 hours varies between 300 and 1,500 grammes; it may be greatly increased by excitants, and irritating medicines and poisons.

Saliva in diseases.

Little is known of saliva in diseases, but the investigations of the future promise results. In diseases, such as salivation under the influence of mercury, rhodanates disappear. The saliva then contains mercury. Many medicinal salts pass easily into the saliva from the blood, such as iodide, chlorate of potassium, and when used long in quantity produce salivation. In diabetes the saliva contains lactates, but no sugar. In the paralytic saliva of hysteric persons leucine has been found. Acid saliva seems to contain lactic acid, and is of course anomalous. The presence of urea has been alleged, but not proved with certainty. In hydrophobia the saliva is the bearer of the contact-poison by which the disease is propagated to other individuals.

Anomalous ingredients.

Digestion of starch.

While the saliva influences starch as indicated, and does not lose its action by the admixture of acid of the concentration of the gastric juice, it certainly does, under ordinary circumstances, not transform the whole of the starch into sugar. The gastric juice does not influence starch, the pancreatic juice to a trifling degree in the same sense as saliva. Deducting all sugar and lactic acid to be met with, it is necessary to assume that other products are formed, which yet elude analysis. Do any of these products find their way into the liver, and are these transformed into glycogen?

Glycogen of the liver.

Glycogen is a kind of dextrine, which was discovered in the liver by Bernard and Hensen. It occurs in three forms, of which one, of the formula $C_6 H_{10} O_5$, is powdery, two others $C_6 H_{12} O_6$ and $C_6 H_{11} O_7$ are gummy. It polarises to the right four times more intensely than dextrose sugar. With a solution of iodine in iodide it gives a dark red colour. It dissolves copper oxyde without reducing it. By sulphuric and hydrochloric acids, saliva, pancreas juice, serum of blood, and cold prepared extract of liver, it is transformed into dextrine and ultimately into sugar. Many physiologists have endeavoured to explain the source and destination of this matter, but as yet without any very complete success. Regarding its origin, it has been found that it could not be formed from sugar, as the portal blood did not contain any. It was not formed from fats. Animal food enabled animals to form it, whence the conclusion was drawn that glycogen originated in albumen. Seeing that the liver decomposes albumen, as proved by the constitution of the bile, this idea has much in its favour, but the experiments upon which it is based admit of different interpretation. Muscle frequently contains dextrine, always inosite (a particular kind of sugar), and lactic acid. All these might enable the liver of the animal which eats the flesh to form glycogen. At present it is at least uncertain from which material the liver forms glycogen; possibly it is formed out of starchy and albuminous matters at the same time, at least most of it is formed (up to 12 per cent. of the weight of the liver in fowls) when these two kinds of food are digested together in large quantity.

Destiny of glycogen.

As the dead liver was found to transform glycogen quickly into sugar, and as some sugar could be found in hepatic blood, it was concluded that glycogen is transformed into sugar, and passes into the blood, to be

there oxydised or changed as required. This view, upon which was based an entire theory, called that of the glycogenetic function of the liver, was received for some years by physiologists in general, until one of its greatest admirers, Pavy, believed that he had discovered it to be erroneous. According to him no sugar is made in the liver in the living healthy body. I showed that his experiments admitted of such variation as to prove either his or Bernard's doctrine. At present the bulk of evidence goes to show, that as a portion only of the starch in the intestines is transformed into sugar and passes into the chyle, so a portion only of the glycogen of the liver is transformed into sugar and passes into the blood. Quantitative experiments on a large scale, combined with the chemolytic method of research, will alone be able finally to decide the matters under discussion.

Mal-assimilation of starch.

Diabetes.

When sugar in considerable quantity exists in the blood, the body cannot deal with it, and excretes the sugar unchanged. Such a condition constitutes the disease termed diabetes, which appears to be a much more complicated disease than its main symptom taken alone would seem to indicate. The oxydation of sugar only is diminished or not accomplished, that of the albuminous substance and fats is rather increased, sometimes enormously so; therefore the carrying power of the blood corpuscles for oxygen cannot be diminished, as has been supposed lately, at least not in all cases of diabetes. There must be a perversion of chemical agency, as proved by the appearance of lactic acid in the saliva and of acetone in the stomach and the urine. On the whole there is at present neither a plausible theory nor a rational treatment of diabetes, as evidenced by the fact that noted physicians now maintain that diabetic patients eating promiscuously everything are better off than patients who abstain from starch and confine themselves to the anamylic diet so elaborately prescribed by Bouchardat. The sugar may be made in the liver or in the muscles, it may be the effect of a change of nervous influence (as suggested by the artificial diabetes of animals after wounds of the fourth ventricle of the brain), or of a failure in the supply of a ferment capable of transferring oxygen to it. The sugar when once in the diabetic blood appears not to be increased or decreased by standing of the drawn blood out of the body, the blood consequently contains perhaps no glycogen. This was ascertained by a special experiment, suggested by the medical officer, made upon the blood of a diabetic patient at St. Thomas' Hospital.

Digestion of the food in the stomach.

Gastric juice.

Pepsine.

Gastric fistula.

The comminuted food mixed with saliva arrives in the stomach and excites this organ to a mechanical and chemical action, termed digestion. The many little rennet glands situated in the walls of the stomach secrete a liquid termed the gastric juice, which in man contains 994·6 pro mille of water and 5·39 of solid and permanently fluid ingredients other than water. Of these 3·0 are pepsine, 0·2 hydrochloric acid, with which perhaps a small quantity of lactic acid is mixed, and chlorides of the alkalies, with some phosphates of earths. Singular is the presence of some calcium-chloride in the juice. The juice has mainly been examined as obtained from persons who by accident had fistulous openings in their stomachs, and upon dogs upon whom such fistulas had been formed by operative interference. It led to the formation of artificial juice, which requires, however, the addition of natural pepsine, and is therefore only in part artificial. It serves, however, for the purpose of studying stomach digestion upon many kinds of food, and of supplying a kind of remedy in diseased conditions in which the natural juice is supposed to be deficient.

Power of gastric juice.

This gastric juice possesses the power of dissolving or reducing to a liquid state albuminous substances, which are either by preparation,

such as boiling, or by nature, insoluble in water. Albumen, caseine, fibrine, syntonine, the albuminous substances of vegetables, gluten, and the collagene tissues or gristle, are under the influence of gastric juice, or of a mixture of pepsine and hydrochloric acid, dissolved to thickish somewhat turbid matters, to which the name of peptones is given. Pepsine may be isolated by mechanical precipitation in the same manner as ptyaline by adhesion to phosphate of lime. It is not itself destroyed during digestion, but is capable of transforming great quantities of solids into fluid by that mysterious influence termed contact action. When the juice is saturated with peptones it ceases to act, but an addition of dilute acid fluid enables digestion of newly introduced albuminous matters to be effected. The secretion of the hydrochloric (and lactic?) acid from the stomach glands is a chemolytic process by which chlorides of alkalies are split up into acid and base. Of this action I shall show the completion of the circle in the biliary function immediately to be described. The origin of the pepsine is the blood, but which ingredient of this fluid yields this curious substance, which is so different from albumen, cannot be told. In the stomach digestion saliva by its ptyaline forms some sugar, the gastric juice fluidifies the albuminous matters, the fats are made fluid and liberated from their tissue connections, vegetable structures are variously disintegrated, and the whole is mixed with water and a small amount of air carried down in the process of swallowing. Other decompositions, as yet imperfectly understood, also take place, as evidenced by the strong odour of the digested matters, and at last the homogeneous mixture of matters, termed chyme, passes through the pylorus into the duodenum.

Peptones.

Chyme.

Peptones.

The ingredients of chyme are starch, sugar, fat, and peptones, or if only animal food had been eaten, fat and peptones alone. There are also undigested pieces of flesh, albumen, caseine, constantly present. It is at present impossible to say what these albuminous matters are. Some physiologists say there is only one substance, others that there are five and more, the statements as well as the experiments upon which they are based being quite irreconcileable with each other. None of these researches have as yet been carried out by means of the quantitative analytical chemical method, excepting the comparison of the composition of the peptones with the original matters. It was found that it was almost unchanged. The peptone solutions are not coagulated by boiling, but precipitated by absolute alcohol. They give Millon's reaction with nitrate and nitrite of mercury. They diffuse easily through parchment paper (dialyse) into water, exhibiting a property towards membranes of the utmost importance for absorption, which albumen possesses only in the very slightest degree. Optically they are characterised by turning the plane of polarisation towards the left.

The coagulation of the milk in the stomach, or by rennett out of it, is supposed by some to be due not to pepsine, but to another ferment which transforms sugar of milk or lactose into lactic acid, and precipitates the soda-albumen or caseine. This matter is problematical.

The quantity of gastric juice secreted daily in the human stomach has been estimated at 10 per cent. of the body-weight, or 16 lbs., other direct observations however lead to 30 lbs.

Gases.

During digestion some gases, consisting of carbonic acid, hydrogen, and nitrogen, are not rarely formed from the digesting food. This may become a distressing symptom in disease.

Duodenal digestion.

Duodenal digestion is a continuation of stomach digestion under greatly complicated circumstances. For the chyme receives additions of bile and pancreatic juice. The physiology of these liquids has been studied upon fistulous openings occurring accidentally in man, or pro-

duced by art in animals. The secretory acts and influences are no doubt well known, particularly their variations under several conditions. But the employment of the secreted matters is by no means so elucidated as to be capable of satisfactory theoretical representation. The pancreatic juice has probably three functions, of which one is the completion of the solution of the pieces of meat and albumen, which issue from the stomach with the chyme; another is the decomposition of fat into glycerine and fatty acid; and a third the emulging of neutral fat and transforming it into a subdivided condition, in which it may pass through the pores of the mucous membrane into the chyle-ducts. It also transforms a small quantity of starch into sugar. All the properties are only possessed by juice which is abstracted from the pancreatic duct of an animal during full digestion, or from a reddened pancreas. This juice is tough or viscid, and contains 10 to 11 per cent. of solids, while the juice which is obtained from a permanent fistula has only five per cent. of solids, and lacks the power of digesting albuminous fragments. It is probable that this deficiency is caused by a degeneration of the gland consequent upon the operative interference. The juice contains an albuminous matter at present undefined, possibly some mucine, mostly leucine, which is present in the parenchyma of the gland in larger quantities, and is more or less alkaline.

Pancreatic juice. Three functions.

Biliary functions.

The liver has an obvious function, and that is to secrete bile. It seems almost superfluous to make such a statement, but the views of physiologists regarding this organ have so often been perverted that it is necessary to recur to elementary principles. The error regarding the function of the liver which has crept into physiology has mainly been caused by the discovery in it of a substance which has the capability of being transformed into sugar, namely the above-described glycogen, also called hepatine, or liver-dextrine; and in consequence of that in itself remarkable and interesting discovery it has generally been believed that the main function of the liver was that of forming sugar. We know now that such is not the case.* The main function of the liver is one of considerable intricacy, and essentially connected with the great features of the process of digestion.

Connexion of stomach digestion with bile function.

Digestion in the stomach is produced by a process in which of chemical ingredients hydrochloric acid takes a main part. In the dog this hydrochloric acid is so strong that the hardest bones are absolutely dissolved. In man such a solution of bones cannot easily take place, but they are certainly corroded when they are introduced into the stomach. The acid which dissolves them in the dog is hydrochloric acid only; in man the acid is probably a mixture of hydrochloric and lactic acid. But although we find in the economy chlorides everywhere, and lactates constantly in the chyle, yet we do not meet with these acids in the free state. We are therefore obliged to assume that in the walls of the stomach a chemical process is constantly taking place by which hydrochloric and lactic acids are being formed. This process is very simple, consisting in the separation of the chlorine from the sodium chloride (or common salt), and the combination with it of a certain quantity of hydrogen. This hydrogen is derived from the water. What then takes place in the glands of the stomach may be stated to be a

* See the articles of Pavy on this subject, Guy's Hosp. Rep. 1858, iv. p. 291; Phil. Transact. 1860, p. 595, and my critical experiments in Brit. Med. Journal, Vol. I., 1860. In these latter the analytical method now generally followed was first used and published; it was afterwards adopted by Pavy, Bernard, Kühne, and others. For confirmation of the variable results see Meissner, Jahresbericht für, 1862, p. 310, et seq. Ritter, Amylum und Zucker in der Leber. Zeitschr. f. rat. Med. 24, 65. Eulenburg, Journ. für Pract. Chem. 103, 108, 1868.

splitting-up of water and sodium chloride, and cross combination of the elements to hydrochloric acid on the one side and sodium hydroxyde on the other.

$$\underbrace{H\Theta_2}_{\text{Water.}} + \underbrace{NaCl}_{\text{Common Salt.}} = \underbrace{HCl}_{\text{Hydrochloric acid.}} + \underbrace{NaH\Theta}_{\text{Sod. hydroxyde.}}$$

The lactic acid is produced from lactates in a similar manner, and in the formula of its formation the place of chlorine in the foregoing formula would be occupied by the formula $\mathfrak{C}_3H_5\Theta_3$ of lactic acid. This is simple and certain. But we find in the body no caustic soda, or sodium hydroxyde, and we are therefore driven to inquire what becomes of this caustic soda so produced.

Why the stomach does not digest itself.

Before it is carried away from the gastric glands by the blood, a part of this sodium hydroxyde has an important function to perform, namely, to protect the stomach against the corrosive action of its own secretion.* It keeps the blood and tissues more alkaline, and prevents the acids and pepsine, which have become more energetic after secretion and mixture with the peptones, from corroding the texture of the stomach. (Such corrosion immediately takes place in cases where the supply of blood to a part of the stomach is interrupted, or where food remains in the stomach undigested after the secretory energy has passed away; gastric ulcer, hematemesis, chronic dyspepsia, or painful digestion with follicular erosion, and other pathological conditions, are produced in this way.) The sodium hydroxyde is soon transformed into carbonate in the blood, and passes through the gastric veins into the portal, and thus into the liver. When we analyse bile and add to it a quantity of acid, we precipitate certain matters, namely, the biliary acids formed by the liver, and the cholophæine; and if we evaporate the liquid we get a large quantity of sodium combined with the acid which we have added. Supposing now that the acid added was hydrochloric, we find at the conclusion of our experiment that sodium has been combining with chlorine and that we have sodium chloride, and that the hydrogen of the acid has again combined with oxygen (hydroxyl) and formed water.

Bile.

$$NaH\Theta + HCl = NaCl + H_2\Theta$$

That is to say, by boiling bile with hydrochloric acid we reproduce the chloride of sodium which before has been decomposed in the walls of the stomach. In our food we take no salt of sodium combined with biliary acid, or any acid that can be transformed into it. We take many substances containing sulphur and nitrogen which can furnish the biliary or special organic part of the bile, but not the soda salts contained in it. Their production is just the function of the liver. The liver splits up or chemolyses albuminous substances or albumen into products of which a part is at present unknown, another part, however, well known under the name of biliary acids and coloured ingredients. They are taurocholic acid, glycocholic acid, cholophæine, bilifuscine, biliprasine, choline, and cholesterine.

Taurocholic acid ($\mathfrak{C}_{26}H_{45}N\Theta_7\mathfrak{S}$) contains all the sulphur of the bile. By this ingredient it manifests itself as a derivate of albumen, which also contains sulphur. Glycocholic acid ($\mathfrak{C}_{26}H_{43}N\Theta_6$) is nitro-

* This function was clearly developed and stated by me in Brit. and Foreign Med. Chir. Review, Oct. 1861, p. 429. At a later period it was made the theme of some interesting experimental inquiries by Pavy (Philos. Transact. 1863) who was, however, not aware of my publication on the subject.

genous only, and free from sulphur. Both acids yield by chemolysis an acid free from nitrogen and sulphur, cholic acid ($C_{24}H_{40}O_5$). But the sulphuretted acid yields as the second product a body containing all the sulphur and nitrogen of the original acid, taurine $= C_2H_7NO_3S =$ dehydrated isæthionate of ammonia, and producible from such; while the other compound acid yields as the second product of its cleavage glykocoll or amido-acetic acid, $C_2H_5NO_2$, which is producible artificially by various processes. The rational constitution of the smaller nuclei is thus shown to be well known; but the same could not be said of cholic acid. Glykocoll appears in an excretion as hippuric acid (in which it is coupled with benzoic) but it is at present uncertain whether this excreted glykocoll has previously taken any share in the composition of bile or not. Taurine, however, is consumed in the body, and its sulphur appears in the excretion as sulphuric acid.

As the chemical nature of cholophæine, bilifuscine, and biliprasine has only lately been evolved by my researches, I refer to the extracts of the technical papers, given in the subsequent pages, for particulars. Their chemical composition is now better known than their physiological meaning, which remain for future inquiry. Cholesterine ($C_{26}H_{44}O$) occurring in the brain and blood is no doubt excreted by means of the bile. It is a polydynamic alcohol, capable of forming ethers analogous to fats. Coloured matters and cholesterine are the main residues of certain diseased processes which terminate in the production of calculi. In a degeneration of the liver, called bacony, considerable quantities of cholesterine remain stagnant in the parenchyma of that organ. The choline of the bile is an organic base of the composition $C_5H_{13}NO$. It is perhaps identical with neurine, a base obtainable from cerebric acid.

Pettenkofer's test.

The biliary acids yield a particular test, called, after its discoverer, Pettenkofer's reaction. When mixed with sugar and sulphuric acid they produce a splendid purple colour. It has been found that other acids, such as lithofellic, also yield this test; and I found, further, that cerebric acid yielded it with rare intensity. I therefore applied the spectroscope, and was glad to discover some means for the distinction of the various acids in the coloured test solution. The biliary acids show two bands, cerebric acid and vitelline only one (see Plate III.). These spectra are, however, difficult to observe, and require sunlight or oxyhydrogen light for their complete development.

Quantity of bile in man.

The quantity of bile secreted in the human body in a day has been estimated at 1,200 grammes, or the bulk which would fill a wine bottle and a half. Conclusions from quantities observed in animals can only be used with caution, as some animals, e.g., the guinea-pig, produce enormous quantities of bile relatively to their body weight, while dogs and sheep produce relatively small quantities. The production is more likely to stand in proportion to the size and weight of the liver (hitherto neglected as a physiological factor) than to the weight of the body, to which hitherto quantities were almost exclusively referred.

The bile in the intestine.

The function of the bile in evidently like its chemical constitution, very complicated. Stored during intervals between digestion, it is mainly secreted as well as expelled from the bladder during digestion, and a particular quantity of it during a peculiar episode at the end of the emptying of the stomach. On being mixed with the acid of the chyme, the biliary acids are set free, but not precipitated, as the soluble taurocholic acid holds the glycocholic in solution. But a precipitate of peptones is nevertheless produced in the mixture of chyme and bile.

This, mixed with the bile-acids and the biliary colouring matter, passes along the intestine as a resinous adhesive substance, to be altered and made absorbable by the many influences of intestinal reaction. It is soluble in alkali, and as much of the intestinal secretion besides gastric juice is alkaline, the transformation meets with no difficulty. The peptone then may pass into blood and chyle as albumen and fibrinogen and fibrinoplastic matter, but the bile is not so easily accounted for. The acids certainly split up, taurine and glycocoll returning into the circulation, but the cholic acid mainly disappears, without leaving any trace in the blood or chyle; neither contain a trace of biliary matter. In the fæces only occurs a small proportion of the cholic acid, amounting in man to from two to three grammes, being perhaps one-eighth or one-twelfth of the entire amount secreted. The cholophæine has been also changed and become insoluble in chloroform. We must therefore assume that the cholic acid is already split up or chemolysed in the intestine, and reaches the circulation in the more simple form of products of its decomposition. The bile influences fats and fatty acids in the manner of a soap. It communicates to the small absorbing tubes an attraction for fat, so that capillarity raises the fat to a higher point than the same vessel would do without bile. Bile then represents the accomplishment of a purpose which we term chemolysis of albumen. But the further uses of bile are numerous and important; the excretion of cholesterine, intimately related to the chemistry of the nerves, and possibly a product of their action; the excretion of choline, of which the objects are continuous; the excretion of cholophæine, of which the objects are at least obscure. Bile precipitates pepsine, and when it regurgitates into the stomach arrests digestion completely. It therefore puts an end to pepsine digestion in the duodenum, and favours the alkaline pancreas-digestion. In disease the bile may be retained and cause jaundice, and slowness of the pulse; or it may be decomposed in a peculiar manner and produce concretions; in man these consist of cholesterine and modified bile-acid, and bilifuscine, with cholophæine and earths; in oxen the cholophæinate of lime predominates, and modified bile-acid with lime-soaps are in lesser quantity. In pigs these calculi contain a peculiar lime salt, which assumes a voluminous crystalline form, when the powder is digested cold with alcohol. The pancreas has in diseases been observed to be degenerated and cancerous; and as in these cases lumps of fat are stated to have been observed in the fæces, this appearance of fat has been ascribed to the failure in the supply of pancreas-juice. In lientery the pancreas as well as the stomach and pylorus is probably at fault.

Fate of peptones.

Changes of bile.

Bile in diseases.

Pancreatic juice in diseases.

The digestion in the small intestine is very imperfectly known, and requires particular and great researches in the future. In this part of the body is the constant and principal seat of diseased processes of the greatest importance, *e.g.*, typhus and typhoid fever, cholera and others, not the least important amongst them the æstival and autumnal diarrhœa so fatal to many persons in every year without special epidemic influences.

Digestion in the small intestine.

Glycerine is a tridynamic alcohol, constructed according to the type of water thrice condensed. In this type there are six atoms of hydrogen replaceable; when three of these are replaced by the radical glyceryl (which is a tridynamic radical) glycerine is formed. Glycerine, therefore, has three atoms of typical hydrogen, which can be replaced by three atoms of a monodynamic body or one atom of tridynamic body. It is not necessary to substitute all the hydrogen at once, when we work synthetically, but in animal bodies all the hydrogen is always replaced

Fats of the human and animal body.

by fatty acids. A fat is thus shown to be a body of the type of three atoms of water condensed to one, thus—

$$\left.\begin{matrix} H_3 \\ H_3 \end{matrix}\right\} \Theta_3''$$

in which three atoms of hydrogen are replaced by one atom of glyceryl^{III}, and three others by three atoms of fatty acid radical^{I}. Tributyrine, a fat occurring in butter, has this formula :—

$$\left.\begin{matrix} \text{3 Monodynamic atoms of Butyryl} = \left\{\begin{matrix} (\text{C}_4\,H_7\,\Theta)^{I} \\ (\text{C}_4\,H_7\,\Theta)^{I} \\ (\text{C}_4\,H_7\,\Theta)^{I} \end{matrix}\right. \\ \text{1 Tridynamic atom of Glyceryl} \quad = (\text{C}_3\,H_5)^{III} \end{matrix}\right\} \Theta_3$$

held together by three didynamic atoms of typical oxygen.

The roman numeral to the right of the radical butyryl signifies that it is a monodynamic radical, and can replace only one atom of hydrogen; but the roman numeral to the right of glyceryl shows it to be a tridynamic radical, which by its one atom replaces three atoms of hydrogen.

The other fats occurring in the human body and in animal food are tripalmitine—

$$\left.\begin{matrix} 3(\text{C}_{16}\,H_{31}\,\Theta_3) \\ (\text{C}_3\,H_5)^{III} \end{matrix}\right\} \Theta_3$$

which is equal to the large formula of

$$\text{C}_{51}\,H_{98}\,\Theta_6,$$

tristearine, a fat abounding in mutton and beef, of the formula

$$\text{C}_{57}\,H_{110}\,\Theta_6$$

and trioleine, a more fluid flat, which abounds in the oils extracted from lower animals and vegetable seeds.

Digestion of fats.

When these fats have passed through the stomach, and after solution of all tissue by which they are held together in the parts of animals, arrive as fluid oils in the intestine, they are acted upon by the pancreatic juice and the bile. The former affects them in two ways. A small portion it decomposes, so that glycerine and fatty acid are formed; another portion it emulges, or makes fit to become subdivided into the very minutest mechanical molecules, and in that state to pass through the small pores of the cylindric cells which cover the villi of the intestine. The fatty acids mostly combine with soda and pass as soaps into the venous blood, and with this to the liver; while the emulged neutral fats pass into the lymphducts, and by them into the venous blood, without passing through the liver. After incorporation with the blood the fat is burned up in the system, particularly the muscles.

Phosphatic emulsion of stearic and palmitic acids.

But there is yet a particular form in which fatty acid is found in the body, namely, emulged in phosphate of sodium solution. When palmitic or stearic acid is boiled with common sodium phosphate, it forms a milky fluid; the acid is so finely subdivided that the microscope can distinguish only the very finest molecules. When this process is applied to neutral fats, or to oleic acid, no effect is produced. The emulsion is a very loose combination, inasmuch as ether extracts the fatty acids. This particular form of fatty acid emulsion occurs in liphæmia, or fatty blood disease, in chylous urine, and in several effusions into internal cavities.* Its formation is a normal occurrence, the phosphate of sodium of the food (bread) yielding the mineral ingredients for the carrying on of the process with the digested fat in the intestinal

* Compare on this subject my researches published in "The Lancet," 1864, Vol. I., p. 434, Liporocele.

canal; if the phosphate be wanting in the food, the bile, which always contains notable quantities, will supply it [and it is to this action of the phosphate in bile that any influence upon fatty acids which it possesses is due, the action upon neutral fats formerly ascribed to it being an erroneous conception]. The anomaly in the above-mentioned diseases is the persistence of the fatty emulsion in the arterial blood, whereby an obstruction of the circulation and consequent effusion (of blood, serum, fatty and fibrinous serum, as in apoplexy, dropsy, chylous urine, and other diseases) is produced.

Fatty degeneration.

Fat having been frequently found in degenerating tissues, deposited in visible manner, in parts where healthy structure shows no visible fat, microscopic anatomists admitted a particular fatty degeneration, in which fat in excess assumed the place of albuminous matters. The heart was supposed to be particularly subject to this disease, to which, however, all other tissues paid tribute. This doctrine, however, is at present in a very unsatisfactory state, and requires much elucidation by researches conducted upon mathematical principles. That fatty degeneration so called may be a very complicated chemical disorder, I showed many years ago by the demonstration of changes in the myochrome of the muscles of the heart, which produced a green granular pigment.†

Chyle.

Chyle is the fluid which the lymphatic vessels of the villi of the intestine absorb from the digested food and carry to the blood. It contains much fat, to which it owes a white milky appearance. It further contains the ingredients for the formation of fibrine, and curdles soon after it is withdrawn from circulation. Then there is potassium-albumen, and the ordinary albumen of serum. There are also lactates, sugar, and urea contained in chyle, besides a certain amount of alkaline salts. Chyle is the material by means of which the blood is constantly renewed. It contains mostly some white and red blood-corpuscles, which leads to the idea that they might perhaps be formed in certain lymphatic glands through which the chyle has to pass. Before entering the blood chyle is always mixed with a considerable quantity of lymph, which differs from chyle mainly by the absence of fat in emulsion. The lymph is transuded serum of the blood, which penetrates into the tissues and there performs its functions; it is then reabsorbed and carried back to the circulation by the lymphatic vessels. There are many derangements of the lymph and chyle which occur simultaneously with diseased glands in scrophula, and in tuberculosis, and it is probable that improper nutrition has the main share in the production of these derangements in a great number of young children.

Chemical constitution of the red blood-corpuscles.

The peculiar shape of the blood corpuscles appears to be partly dependent upon their chemical constitution. This latter is the product of their own powers and their interchange with those of the surrounding serum. They have a certain specific gravity, which is maintained or varied (in diseases, in different classes of animals) by the quantity of certain chemical ingredients which are within them. Amongst these latter most notable by its red colour, and in the first place by its chemical constitution, is hematocrystalline or cruorine.‡ This substance contains carbon, hydro-

Hematocrystalline or cruorine.

† *See* Transact. of the Pathol. Society, 6, 134; and Quarterly Journal of Microscopical Soc. No. 14.

‡ When the blood crystals were first discovered and their various shapes and properties found out (Funke, Kunde), it was believed and stated (Lehmann) that they consisted of a colourless substance (hematoglobuline) to which a coloured matter (hematine) adhered like a dye. As long as the researches on this subject moved on the microscopic field only this idea was plausible; for many crystals are actually so thin as to appear colourless under the microscope. But the chemical and spectroscopical researches of the last few years have established the error of this conception and substituted the doctrine of the text. Cruorine is a synonym which was first proposed by Denis, and has lately been again revived by Stokes.

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gen, nitrogen, iron, sulphur, and oxygen, in the proportions indicated by the following formula : $C_{600}H_{960}N_{154}FeS_3O_{177}$. This leads to an atomic weight of 13,280, but if the atomic weight be determined by the quantity of iron, an atomic weight of about 13,000 is arrived at. Persons who have not studied this branch of chemistry, and who perhaps in their handbook, do not read of atomic weights rising above 500, may wonder at the high atomic weight here assigned to hematocrystalline. But this body can now be obtained pure in drachms and ounces, and the analyses of crystals by Lehmann, Schmidt, H. Seyler, and others, have always shown them to contain four-tenths per cent. of iron. The crystals are mostly of the rhombohedric system, and appear in tetrahedra, octahedra, with and without prisms, or in prisms only. Their watery properly diluted solution, when examined in the spectroscope, shows two remarkable bands of absorption, and obscuration of the blue and violet end of the spectrum, as represented in fig. 1 of Plate I. As the blood of all vertebrate animals, when viewed within the living blood vessels, shows the same bands, we can assume that hematocrystalline is present in it as such, and not formed by the process of preparing the crystals. Hematocrystalline can be deprived of its oxygen, and then its spectrum changes to that of reduced hematocrystalline (fig. 2, Plate I.) Shaking with oxygen restores the double-banded spectrum. The two bands therefore belong to arterial blood, the one band to venous blood (Stokes). Hematocrystalline contains as proximate constituents an albuminous body, which after separation remains amorphous and colourless, and hematine, which retains the colouring power, the spectral influence upon light, and the iron of the original substance, though all varied in kind, proportion, and quantity. Hematine has an atomic weight of about 620, and from 7·5 to 8 per cent. of iron. It yields many remarkable products of decomposition which will be treated of lower down. Its spectra in various solvents and in the reduced state, and the spectra of a number of new derivates, are represented in figures 3 to 10 of Plate I., and figs. 1 to 5 in Plate II. The optical and chemical phenomena of hematocrystalline and hematine are applicable to medico-legal research, as affording the most certain diagnosis of blood upon the smallest quantities of material. A diminution of hematocrystalline in the body constitutes the disease termed "chlorosis" or "anæmia." It is either a specific ailment, or a symptom and consequence of chronic disorders, or acute, particularly tropical fevers.

Shape of crystals.

Spectrum of oxydised and reduced hematocrystalline.

Hematocrystalline splits up into albuminous body and hematine.

Besides hematocrystalline the blood corpuscles contain a quantity of cerebric acid, with an atomic weight of certainly not less than 2,115. This has been variously called myeline (Virchow), protagon (Liebreich), and other names, but it is the same body as that which can be extracted from the brain. We further have in blood corpuscles a certain quantity of what is called stroma. This is merely a name for a substance which is supposed to give them a shape. The stroma remains when the other bodies are extracted. It is a kind of chemical skeleton, and can be isolated (by freezing, for example) and investigated (Rollet). It seems to be very different from the albuminous matters combined in hematocrystalline, for it is soluble in ether, alcohol, and chloroform, when these agents are dissolved in serum. But it contains a small quantity of fibrino-plastic substance (Alex. Schmidt), namely paraglobuline, sometimes also termed globuline. This remains insoluble when the blood corpuscles, previously separated from serum by solutions of salt, are deprived of hematocrystalline by water. The gelatinous paraglobuline, after shaking with water and ether, is soluble in solutions of salt, dilute alkalies, and water containing

Cerebric acid in blood corpuscles.

Stroma.

Stroma contains paraglobuline.

one per mille of hydrochloric acid. Brought in contact with fibrinogenous solutions it frequently produces fibrine.

The blood-corpuscles carry oxygen, which has great affinity for hematocrystalline, from the lungs to the most distant or hidden and internal parts of the body. They there yield it up to the tissues, principally the muscles or the oxydisable matters contained in their juices, and the tissues, thus oxydised, return the carbonic acid, water, urea, and other products into the blood. The muscles may either oxydise immediately or store the oxygen in large quantities by means of their red colouring matter, which is identical with hematocrystalline, particularly during sleep. Although the carbonic acid affects the colour and condition of the blood corpuscles, nevertheless the latter are not carriers of the carbonic acid. This gas is in the serum. It is there partly dissolved in the same manner as in soda or Seltzer water, but to a great extent it is combined with alkaline bases, particularly sodium. When the blood-corpuscles of the venous blood arrive in the lungs, they have undergone a change which consists in the partial oxydation of a small quantity of their hematocrystalline, and this is transformed into an acid which I will call hematic acid. This blood-acid contains nitrogen. It is not similar to any of the acids we know. It is not volatile but fixed; it is evolved from the blood corpuscles and passes into the serum at the very moment when the former arrive in the small breathing cells of the lungs. There the blood acid combines with the sodium and the carbonic acid is set free, and is left to take its course, with water-vapour, through the lung tissue into the respiratory passages.*

Function of the blood-corpuscles.

Carbonic acid is in the serum.

Hematic acid.

In my research on cholera I have shown that the serum of the blood, in consequence of the alvine flux changed in its constitution in that disease, refuses to perform the functions which it performed before. It exhausts water and other matters from the blood-corpuscles, and the latter thereupon cease to carry oxygen; oxydation does not take place any longer, hence the temperature falls, and the algid condition of cholera is produced. In yellow fever, and in a disease which occurs in England, intermittent hematuria, the hematocrystalline of a portion of the blood corpuscles leaves them, and in the one disease decomposes and colours the skin yellow, in the other appears in the urine with a red or reddish-brown colour. A similar decomposition takes place in some cases of pyæmia, and in poisoning by arseniuretted hydrogen, and by the bite of venomous serpents. Several poisons, such as sulphuretted hydrogen, carbonic oxyde, hydrocyanic or prussic acid, kill or injure by decomposing the hematocrystalline, or combining with it and keeping the oxygen out. Of these I will treat below, when considering the application of the spectroscope to pathology and toxicology. Thus the study of many diseases requires an intimate knowledge of the constitution of the blood corpuscles. The value of this we have only just begun to appreciate, and the chemical and optical methods of investigation applied with rigorous accuracy will bring us not only the explanation of normal phenomena at present remaining obscure, but also useful practical information on the nature of diseases, processes of poisoning, and their treatment by prevention or cure.

Blood change in cholera.

* The excretion of carbonic acid from the lungs is an act of specific secretion, to which the presence of oxygen (and nitrogen) may be a supplementary advantage (as favouring diffusion), but is not essential. Hüter's observation of twin fœti, which were born living within the uninjured membranes and surrounded by the liquor amnii, and in that condition exhaled gas, are to me conclusive evidence of this, as also of my proposition that the act of first breathing is an act of secretion. This theory is fertile of explanations of many dark phenomena, such as the peculiar power of new-born children to sustain prolonged states of asphyxia.

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Coagulation of the blood. Fibrinoplastic and fibrinogenous matter.

One of the most remarkable properties of the blood is its power of coagulating or setting shortly after it has left the body. Of this phenomenon many ingenious theories have been given, but none has yet satisfied the demands of exact chemical science. The latest and most plausible one is that of A. Schmidt, according to which the serum contains two substances, which have the power of combining with each other or forming fibrine, or the substance which produces the phenomenon of the curdling of the blood, as caseine produces that of the milk. One of these matters has been termed fibrinoplastic substance (paraglobuline) contained in serum and corpuscles, the other fibrinogen, contained also in serum and other fluids of the body. There is no doubt that substances answering to these descriptions can be isolated, and when brought together mostly form fibrine. But what is not yet proved is that they combine in atomic proportions. It is just possible that the paraglobuline only acts as a ferment like rennet, and transforms fluid fibrinogen into gelatinous, solid, or fibrous fibrine, by the power which in chemistry is termed contact action. But even should this theory be confirmed as at present shaped, it would fail to afford any answer to the obvious question after the inhibitory power which prevents these bodies from reacting upon each other in the circulating blood. The question of the cause of the coagulation being answered would make room to the question of the cause of the fluidity and non-combination of these bodies during life and circulation. This would no doubt be a progress, but not a solution. It is a fact that blood while in contact with the inner surface of healthy blood-vessels in living bodies, even when prevented from flowing by double ligatures, does not coagulate. Even coagulated blood, when placed into the cavity of the excised heart of a turtle becomes fluid again. From these and similar facts the living walls of blood-vessels were said to be the agencies which kept the blood fluid (Brücke). But such a statement is only a circumscription not an explanation of the fact, which therefore requires further study and investigation.

Circumstances under which blood keeps fluid.

Fibrine contains albumen, physiolysis.

It must always be borne in mind that by the method of physiolysis, or putrefaction conducted upon certain principles and with certain precautions, fibrine yields albumen, and that consequently the atomic constitution of fibrine must be more complicated, and its atomic weight higher than that of albumen.

Chemical constitution of the serum.

Paraglobuline.

Sodium and potassium albumen.

The yellowish liquid which remains when the fibrine has been allowed to set in the blood, and to enclose and retain in its contracting meshes the blood corpuscles, is termed the serum. It contains yet a quantity of paraglobuline, of which only a small portion has been used up towards the formation of fibrine. It further contains sodium albumen (or caseine of serum, Panum), and a very small quantity of potassium albumen. The paraglobuline is precipitated by carbonic acid from serum diluted with 10 water, the albuminates dissolved in combination with the alkaline metals are set free by little acetic acid. But the ingredient of serum which is present in the largest quantity (7·9 to 9·8 per cent.) is the albumen particular to the serum, or blood albumen, as distinguished from the albumen or white of egg. This is completely precipitated by boiling in the presence of a little acetic acid. If no acetic acid is present, sodium albumen, formed during the process of coagulation, remains in solution.

Blood or serum albumen

Neutral fats and soaps.

Free fatty acids in emulsion.

The serum contains neutral fats and soaps in solution or suspension, in the latter case being rendered milky or turbid thereby. In cases of disease which I have made known the serum also contains free fatty acids. These acids are emulged with the phosphate of sodium of the serum, and after extraction by ether are again easily emulged by boiling with a solution of common sodium phosphate in water. A similar emulsion I have shown to occur in so-called chylous urine, and in

certain effusions in the scrotum, termed variously milky hydrocele or lactocele. The serum further contains cholesterine, creatinine, urea, and hippuric and lactic acid in small quantities. In gout, uric acid as urate of sodium and calcium is found in it; in diabetes, sugar. In jaundice, biliary colouring matter, or cholophæine; and in leukocythæmia, formic acid, xanthine, and other matters.

Mineral salts in serum.

Of inorganic salts the serum contains sodium chloride, sodium dicarbonate, and calcium phosphate, small quantities of magnesium phosphate, still smaller ones of potassium salts. The chemical operations of the serum (and blood on the whole) employ sodium salts mainly, while those of the muscles chose salts of potassium mainly. We have seen how the function of the liver employs the sodium as the principal mineral base for its peculiar acids. But an explanation of this strict separation has yet to be found. We are more confused than enlightened by the discovery of the apparent paradox that fish, living in a medium abounding with sodium salts, should form a bile the mineral base of which is potassium.

Gases in serum.

The serum contains nearly the whole of the carbonic acid contained in the blood, particularly when it becomes venous. This is present in two forms, the one dissolved and removable by the vacuum, the other combined with sodium as carbonate and dicarbonate, and dislodged only by acids and boiling. It is also possible that the sodium phosphate attracts a portion of carbonic acid and holds it in peculiar loose combination.

The particulars of the changes which the ingredients of serum may undergo in the febrile and zymotic diseases will be discussed under the respective headings.

The physiology of the gases of the blood, of the oxygen, nitrogen, and carbonic acid contained in its modifications of arterial and venous character, has only lately been perfected by instruments and methods satisfying all demands. These methods will in future have to be applied to pathological research on a more extended scale.

Quantity of blood in a man.

The total quantity of blood contained and circulating in a living man has for many years been greatly over-estimated, owing to fallacious conclusions derived from the practice of blood-letting. The best methods available about 10 years ago reduced the quantity to 7·7 per cent. of the weight of the body (Bischoff). But this has to be again reduced, as in these processes the myochrome was not deducted from the hematocrystalline, by the quantity of which the blood was estimated. Seven per cent. of the weight of the body will probably be a more correct estimate of the quantity of the blood than any other hitherto made.

Striated muscles.

The striated muscles consist of particular contractile matter, arranged in layers within a fine membranous bag (sarcolemma) and connective tissue. The contractile matter is arranged in disks consisting of syntonine, which are laid close together, separated and surrounded, however, by a particular plasma. This can be isolated from muscles treated at the freezing point, taken out of the animal just killed, or from cold-blooded animals, such as frogs. The plasma is alkaline, and coagulates on standing like blood; by beating the coagulation is favoured. The coagulum is termed myosine; it is flaky, never fibrous, and more transparent than fibrine. Plasma dropped into warm water coagulates instantaneously, and deposits pure myosine. Like fibrine, myosine decomposes peroxyde of hydrogen. By solution in dilute acids it is transformed into syntonine. This is the name of the solid part of the flesh tissues, the particular fibrine of flesh of Liebig, which, insoluble in water, can be extracted from the insoluble part of meat by dilute

Muscle-plasma.

Myosine.

Syntonine.

Muscle-serum.

First albuminous matter.

Potassium-albumen.

Serum-albumen.

Myochrome.

Beef-tea.

Ingredients of beef-tea.

Extract of meat.

Residue of extracted meat.

acids in large quantities. The muscle-plasma, after coagulation of the myosine, leaves the muscle-serum. This becomes quickly acid, like all meat on keeping, and on neutralization deposits an albuminous substance. The fluid on acidification precipitates albumen which was in combination with potassium. This precipitation occurs in the meat naturally by formation of paralactic acid, which at first shares the potassium of the phosphate, and transforms it into acid phosphate. To this belongs the acid reaction of kept meat. Only when excess of paralactic acid in its free state is present does the albumen separate from the potassium-albuminate. Besides these two modifications the muscle-serum contains the ordinary serum albumen of blood. There is also contained in the serum of the red-coloured muscles a coloured albuminous matter, myochrome, identical with hematocrystalline. In white muscles this matter seems to be absent. When flesh is extracted with water the albuminous matters contained in this solution are precipitated by boiling (albumen curdles at 65° C. hematocrystalline only at about 90° C), a faintly yellow broth is obtained, which when made of mutton retains that name, but when made of beef is popularly termed beef-tea. This mysterious fluid, which is of great dietetic value to the healthy and the sick, contains a great number of remarkable ingredients—creatine, $\mathfrak{C}_4H_9N_3\mathfrak{O}_2$; creatinine, $\mathfrak{C}_4H_7N_3\mathfrak{O}$, the former a neutral body, the latter a powerful organic base, which also appears in the urinary excreton; uric acid, $\mathfrak{C}_5H_4N_4\mathfrak{O}_3$; xanthine, $\mathfrak{C}_5H_4N_4\mathfrak{O}_2$; hypoxanthine or sarkine, $\mathfrak{C}_5H_4N_4\mathfrak{O}$; guanine, $\mathfrak{C}_5H_5N_5\mathfrak{O}$; all of which appear in the urine of man or of the lower animals; taurine, the body obtainable from taurocholic bile-acid, and which may therefore be perhaps formed in the muscles, and carried to the liver, or be formed in the liver and carried to the muscles, or be formed in both in different ways; inosic acid $\mathfrak{C}_5H_6N_2\mathfrak{O}_5$, and acids of analogous composition; further bodies free from nitrogen, as paralactic acid $\mathfrak{C}_3H_6\mathfrak{O}_3$; formic, acetic, and butyric acids; glycogen, the same as that in the liver; dextrine; sugar or grape-sugar; and a particular kind of sugar also found in the green shells of French beans, namely, inosite $\mathfrak{C}_6H_{12}\mathfrak{O}_6 + H_2\mathfrak{O}$. The total of these bodies which are known amounts to two grammes from the extract of 1,000 grammes of flesh; but the total amount of extract obtained is 12 grammes of organic substances. Consequently five-sixths of the extracts of meat are at present quite unknown to us. The extract of the meat of animals, oxen and sheep, has now become an article of wholesale manufacture and of trade. It contains 18 per cent. of salts, of which nearly half the weight is potash. The economic advantages of this extract are the direct result of the purely scientific studies of Baron Liebig, and have made his name literally a household word. The residue of meat from which the extract has been pressed contains all matters insoluble in water, syntonine, myosine, sarcolemmata, with nuclei, and fat. Some of this fat is visible under the microscope in the fibre, but some is invisible and dissolved, though not as soap. The residue contains phosphate of potash in insoluble combination with an organic matter, but no chlorides.

The muscle is a machine for the transformation of chemical into mechanical force, and for the storing and exercise of that force. The exercise is partly constant and involuntary, partly intermittent and subject to the will. The loaded muscle is alkaline, full of disposable oxydisable matter, and of oxydant, namely oxygen. The nerves of motor influence effect chemical contact and immediate contraction of the various elements. The muscle becomes acid during work, and gives off large quantities of

carbonic acid. The disintegration of its albuminous matter seems hardly to be increased immediately, but that of the carbonaceous substances is evident. Muscular exercise does not increase the excreted urea quantity, but that of the carbonic acid exhaled perhaps to tenfold the amount excreted in rest during equal times. The muscle participates in all febrile diseases of the body, and is frequently the seat of idiopathic processes. In typhoid and typhus fever it becomes disorganized in a high degree, losing structure, and assuming a yellow appearance. In fatty degeneration it loses its contractility and shows fat in a free state amongst changed structure elements. In death from carbonic oxyde it has a red florid colour due to the combination of the poison with its hematocrystalline; in tetanus it is spasmodically contracted, changed, and frequently torn; in hydrophobia it is similarly injured and torn; in trichiniasis it is the specific seat of a parasite, the trichina spiralis, which does not live in any other tissue. The changes of the muscles in diseases have only just begun to be studied, and cannot fail to be found of the utmost importance. As the muscle during life takes up oxygen from the blood, besides nutriment of the most varied kind, and renders back to the venous blood carbonic acid, water, and a host of refuse matters, so does the dead muscle, its coagulated myosine notwithstanding, continue some time to breathe, take up oxygen and give out carbonic acid. At last its atoms take a new direction, and physiolysis or putrefaction commences. The muscle yields the products common to the albuminous substance, tyroine, leucine, volatile acids and alkalies, &c. The same substance is obtained by chemolysis; leucine was first discovered (by Braconnot) in the decomposed muscular tissue. By continuing the study of chemolysis we shall probably be able to learn more about the changes of the muscles in disease, as well as about the ingredients of flesh extracts which are at present unknown.

Diseases in muscles.

Dead muscle.

Physio- and chemolysis of muscle.

The smooth or organic involuntary muscular fibres contain some ingredients similar to those of the striated, but require to be better studied—a matter of great difficulty, as they cannot easily be isolated.

Involuntary muscles.

The nerves and brain consist mainly of minutely thin long fibres, and of cells standing in connexion with these fibres. These fibres are membranous tubes, filled with a peculiar nerve or brain marrow. When the nerves are taken out of the living body they change quickly, and the marrow of the tubes separates into two substances—a central one, the cylinder axis, and an outer or periaxial portion. This change is not yet quite explained. Possibly it may consist in a coagulation of the axial cylinder, which causes its contraction. The axial cylinder is, however, already in life of a different chemical composition than the periaxial tube, for it shows no effects in the polariscope, while the periaxial part exhibits dark or light crosses. The chemical constitution of these matters is perhaps the greatest problem of organic and physiological chemistry. A consideration of all researches since the time of Vauquelin tends to show that brain matter is constituted similar to the hematocrystalline of the blood; that it contains an albuminous matter to which is combined a substance containing nitrogen and phosphorus; that its molecule must therefore be very complicated and large, and that the matters hitherto extracted from the brain are at the most detached proximate nuclei, or single stones broken out of the mosaic picture which its molecule may be imagined to represent. The principal one of these detached nuclei is a body of which a small quantity can be extracted from brain matter by boiling alcohol, and which has been variously termed brain-wax, brain-fat, cerebrine; but by Frémy, who first obtained it pure and determined its composition, was found to be an acid, and termed cerebric acid. Lately Liebreich, having examined the

Ingredients of the brain and nerves.

Brain-fat, cerebrine, cerebric acid, protagon.

Fatty acid, glycero-phosphoric acid, neurine.

Cholesterine.

Caseine, albuminous matter.

Various ingredients.

Ash.

Myeline.

Connective tissue.

Cement mucine.

Gelatine or glutine.

same substance, gave it the name of protagon, but without any valid reason. This cerebric acid has the empirical formula of $C_{116} H_{240} N_4 P O_{22}$. It appears in crystalline needles, and gives remarkable reactions, of which several new ones will be described in a subsequent paragraph. By decomposition it yields fatty acids, glycero-phosphoric acid ($C_3 H_9 P O_6$), containing the whole of its phosphorus, and neurine ($C_5 H_{13} N$), containing all its nitrogen. Much of it is contained in the brain in a state of such firm combination that even concentrated sulphuric acid does not easily set it free. There is further in the brain cholesterine, the peculiar alcohol of which a quantity is constantly excreted with the bile. The albuminous substance of the brain has not yet been isolated completely; a small quantity can be extracted as potash-albumen (or caseine); another quantity is insoluble in water, and its presence can only be deduced from the curdling of brain matter by boiling, and from the products of the chemolytic process, which, as I have found by researches to be alluded to, yields all the products of chemolysis of albuminous matter, volatile acids and alkalis, leucine, tyroine, and other substances. Of other matters there are found in the brain substance lactic and a volatile acid, and inosite; uric acid, xanthine and hypoxanthine; creatine. Sugar is sometimes found, and more rarely a substance which gives reactions similar to starch, and the study of which may perhaps throw some light on the peculiar disease termed amyloid degeneration. In diseases, leucine and a homologue of it appear sometimes. In others much urea collects in the brain and in the cerebrospinal fluid, which fills the cavities of the brain and spinal marrow. The largest quantities of urea are met with in cholera, in which the cerebrospinal fluid may contain as much as ordinary urine. In a case of softening of the brain Lehmann found glycero-phosphoric acid in the softened matter. The brain substance contains 25 per cent. of solids only, and 75 per cent. of water. Its ash contains acid phosphates and a quantity of free phosphoric acid, a residue of the destroyed cerebric acid. Besides much potassium, some sodium, little magnesium and calcium, the ash always contains a notable quantity of iron. The ash of the grey matter of the brain is always alkaline, owing in part to the circumstance that it contains less cerebric acid than the white matter. When an ethereal extract of brain matter is mixed with water, and seen under the microscope, it swells and projects various peculiar forms of matter in various directions. The phenomenon is due to cerebric acid, which is dissolved in soap; it has given much and varied amusement to microscopists.

The connective tissue forms tendons, fasciæ or envelopes of muscles and limbs, ligaments of joints and capsules, and binds all organs of the body together. It consists of fibres, of a cement uniting these to a tissue, of cells or so-called corpuscles, and is interspersed with elastic fibres. It is soaked with potassium-albumen. The cement is soluble in caustic lime and in baryta-water; it is reprecipitated by acetic acid, and then manifests itself as mucine, identical with that of the salivary glands and embryonal tissues, *e.g.*, the umbilical cord; the fibrillæ remain isolated, but mixed with the corpuscles or cells and their nuclei, and with elastic fibres. In acetic acid the fibrillæ are transformed into glutine or glue. The same transformation is effected by prolonged boiling in water. The elastic fibres resist this treatment. Both sorts of fibre by chemolysis yield tyroine, leucine, volatile acids, and alkalies, but the gelatine is distinguished by yielding glycocoll, the lower homologue of leucine, while elastic fibres yield more leucine. Mucine yields sugar by chemolysis, and in this respect resembles chondrine, but it also yields much

tyroine, up to 7 per cent. These various data have given rise to the idea that mucine and glutine were products of a peculiar cleavage of albumen, but albumen has not yet been found to yield any sugar. The cells or corpuscles of the connective tissue consist of a semi-fluid matter which is termed the protoplasma, and of nuclei. In the protoplasma of the cells of the connective tissue pigment is frequently deposited (choroid, rete Malpighii of negro, bronzed skin disease, freckles, melanotic cancers,) which is black or brown. Of this pigment very little is known, but my researches promise to throw some light upon its nature and origin.

Protoplasma.

Pigment.

The fat tissue is made up of cells, in the interior of which fat is deposited, and of connective tissue. The fat cells are probably peculiar organs, but the cells of the connective tissue above described are probably able to deposit fat within their substance under certain circumstances. Some fat tissue remains permanently in the body, some may lose its fat during starvation or disease, and regain it. The fats in the human fat tissue are mostly those described in the paragraph on digestion, tri-stearine, tri-palmitine, and tri-oleine. The fatty tissue is subject to hypertrophy, or excessive infiltration; there also peculiar colorations are observed in several diseases, *e.g.*, consumption or phthisis. Newly formed fat tissue is observed in the fatty tumours or lipomata. Fat in tissue may originate in several ways; it may have been eaten with the food, and after absorption only been carried to the cells; or it may be formed from sugar, dextrine, and glycogen; or, lastly, it may owe its existence to the decomposition of albumen. Thus the cholic acid of bile might easily yield any of the fatty acids, and sugar the glycerine. But the proofs for any of these processes have not yet been furnished.

Fatty tissue.

Fatty tumour.

Cartilage contains peculiar cells and chondrinogen, or a substance which by boiling becomes chondrine. This matter gelatinises like gelatine, but is not soluble in acetic acid, on the contrary precipitated by it. Boiled with hydrochloric acid, chondrine yields sugar.

Cartilage.

The chemical composition of the cornea is similar to that of cartilage, particularly the hyaline variety.

Cornea.

The cartilages are subject to a degeneration which terminates in ossification.

Ossification.

The cartilage surfaces of joints are lubricated by a fluid which is termed synovia. It contains about 94 per cent. of water, 3·5 of albumen, 0·5 of mucine, and more than 1 per cent. of ash. Its origin is not yet satisfactorily explained. During diseased conditions of joints much synovia can be detected; the collection of excess of synovia in a joint constitutes hydrarthron.

Synovia.

Hydrarthron.

A matter similar to chondrinogen is hyaline, of which the cysts of old echinococci are composed. Boiled with dilute sulphuric acid it yields, like the chitine of insects and articulate animals ($C_9 H_{15} N O_6$) dextrose fermentescible sugar.

Hyaline.

The bones consist of a peculiar combination of organic matter with mineral earthy phosphates, and contain as accessory matters marrow, bloodvessels, and cellular nuclei in the cavities called bone corpuscles.

Bones.

The organic substratum is called osseine (a name which it would be better to apply to the entire bone tissue), the mineral matters are termed bone-earth. The osseine is obtained by extracting the bone-earth with dilute hydrochloric acid. It retains the structure of the bone substance, which is disposed in concentric layers round a tubular centre. Osseine dissolves on boiling in water like glutin, but differs from the latter in several particulars, although the product of the solution in hot water is true gelatine. Of osseine purified bones contain from

Osseine.

APPENDIX.

No. 7. *On Chemical Identification of Diseases, by Dr. Thudichum.*

29·5 to 30·9 per cent., with which 68·1—69·4 per cent. of earthy salts are in combination. The regularity of these proportions has led to the assumption that bone is a chemical compound in definite atomic proportions of osseine and earths, and not merely a tissue in which earths are deposited. Some remarkable experiments show that gelatine and earthy phosphates have a peculiar attraction for each other. Thus a mixture of gelatine and bone-earth in hydrochloric acid, when neutralised by ammonia, deposits bone-earth with 20 per cent. of gelatine; vice versâ when tannic acid is added to such a solution tannate of gelatine with much bone-earth is precipitated. Bone-earth contains 9·1 per cent. of calcium carbonate, 87·7 of calcium phosphate ($3\ \mathrm{Ca}\ P_2\ O_8$), 1·7 of magnesium phosphate ($3\ \mathrm{Mg}\ P_2\ O_8$), and 3 per cent. of calcium fluoride ($\mathrm{Ca}\ Fl_2$). The nutrition of the bones proceeds from their surface towards their cavities. Certain dyes, given with the food, penetrate into the bones and stain them. The idea formerly combined with this experiment, namely, that the bone was rapidly renewed from without and absorbed in the marrow cavity, is probably quite untenable. In several important diseases the bones are greatly affected, and become either brittle, or soft and bend. Such diseases are rhachitis, or rickets, common in children, and the osteomalacia of pregnant women, and that particular form which attacks aged persons. In these diseases the bone-earth falls to about 30 per cent. of the dry bones, while the osseine rises to 60 and 80 per cent. The osseine at the same time changes its chemical character, by a curious tissue transformation, starting from the marrow cavities, and does no longer yield glutine. It seems that the agent by means of which in this no doubt complicated process the earths are removed is lactic acid, which under these circumstances, and not in health, is found in and about the bones. These diseases urgently call for chemical investigation.

Bones dyed with madder.

Rhachitis. Osteomalacia.

Lactic acid in bones.

Teeth.

The teeth are bones, of which a part, the root, is constructed like ordinary bone, the top or crown upon a particular plan, round many minute tubes; this latter tissue is termed dentine. The outer hard covering, the cement, is an epithelial formation, containing only 4 per cent. of organic matter, 92 per cent. of earthy phosphates, and 4 per cent. calcium fluoride.

Dentine.

Cement.

Pus.

Pus is a product of disease or injury. It consists of a serum, in which many corpuscles, resembling the white corpuscles of the blood, are suspended. From the corpuscles, separated by filtration, myosine (see muscles) is obtained. This substance is probably the instrument of the contractility of these bodies. The serum has fibrino-plastic properties, *i.e.*, contains paraglobuline, which can be precipitated by carbonic acid; on addition to the filtrate potassium albuminate or caseine is precipitated, and after the removal of this latter serum albumen is precipitated by heating. Mucine has never been found in pus. Chondrine and glutine have been found in the filtrate from the pus coagulated by boiling. They are probably connected with the corpuscles, like the glutine which is found in the blood in leukocythæmia. Pus, probably in its corpuscles, contains cerebric acid and cholesterine; the latter is deposited on standing. During standing and decomposition pus also deposits palmitic and stearic acid in crystals, oleic acid after addition of acetic acid. Good or healthy pus from wounds contains no volatile acids, but decomposing pus yields volatile acids of the fatty series, formic, butyric, valerianic, in short products of putrefaction. Pus from abscesses, from phosphorus disease, and ulcerating cancers, contains an acid, which as it gives a rose-pink reaction with chlorine

Myosine in corpuscles.

Paraglobuline, caseine, and serum albumen in serum.

Chondrine and glutine.

Leukocythæmia.

Cerebric acid. Cholesterine.

Fatty acids.

Volatile fatty acids.

water, has been termed chlorrhodinic acid. A similar substance can be obtained from decomposing pancreas extract and lymphatic glands. Pus may contain leucine, tyroine, xanthine, and uric acid ; in the pus from jaundiced persons biliary acids and cholophæine are found; in that from diabetic patients sugar. The so-called blue pus derives that colour from a kind of vibrio, which yields its pigment to chloroform, from which it is obtained in crystals, and termed pyocyanine. The solid matters contained in pus amount to from 10 to 15 per cent.; its ash is similar to that of blood, contains 72 per cent. of sodium-chloride, and more potassium-salt than blood-serum. A knowledge of the composition and products of decomposition of various kinds of pus from abscesses, ulcers, wounds, &c., is of the utmost importance for the study and treatment of reactive fever after wounds and operations, of various forms of blood disease termed septichæmia, and pyæmia. In all these affections pus, or products of its decomposition, are absorbed or enter in a more grossly mechanical manner into the lymph and blood, set up an acute patholytical process which leads to violent attacks of shivering, fevers, sweating, diarrhœa ; then, in the case of septichæmia and pyæmia to secondary deposits of pus or other fluids in various organs and cavities, particularly the lungs and liver, and ultimately, and in nearly all cases, to death. Against this fatal disease a particular kind of treatment of wounds, the so-called antiseptic treatment, has lately been devised, and is now under the consideration of surgeons.

Chlorrhodinic acid.

Blue pus.

Pyocyanine.

Pyæmia.

The function of the spleen is not well known, but seems connected with the elaboration of certain constituents of the blood and certain processes of digestion. The organ contains much blood, and a separation of its tissue and juice from its blood has not yet been effected. The fresh spleen is alkaline, but soon becomes acid. The watery extract contains hematoerystalline and the other ingredients of blood, and besides a peculiar albuminous matter which on combustion leaves phosphoric acid and iron oxyde. It encloses some cholesterine. After removal of all albuminous matters there are in the extract of fixed acids the lactic and succinic, of urinary products hypoxanthine, xanthine, and uric acid, of volatile fatty acids formic, acetic, butyric, of amido-acids leucine ; of alcohols there is inosite in considerable quantity. These ingredients show that chemical processes of various kinds must be carried on actively in the spleen. They are, however, not indispensable to life, as animals from which the spleen has been removed by operation continue to live without any perceptible disturbance. In leukocythæmia the spleen is frequently very large, and weighs up to nine and ten pounds. If it be found small in that disease the lymphatic glands are certainly enlarged. The spleen is sometimes subject to (here) mis-called amyloid degeneration. Although in this state it gives many reactions of albumen it is indigestible in artificial gastric juice ; it gives no sugar by treatment with sulphuric acid, and is little prone to change by artificial or natural influences.

Spleen.

Peculiar matter.

Ingredients of water-extract.

Waxy degeneration of spleen.

The thymus gland is a mysterious organ situated in the chest in front of the lungs. It becomes of less importance to the adult than it probably is to the fœtus "in utero." It contains albumen, collagene, elastic tissue, a little fat, leucine, xanthine, hypoxanthine, succinic and lactic acid, and perhaps also volatile fatty acids and sugar. In the progress of the involution of the thymus the amount of sodium contained in it is nearly doubled.

Thymus gland.

The thyroid contains nearly the same chemical constituents as the thymus. It would be very confusing that the constituents of glands of the most varied connection and situation are identical, were we not reminded that the defined ingredients are perhaps only one-fourth or

Thyroid.

one-sixth of the whole of the ingredients, and that specific differences may therefore be discovered upon the ingredients which at present are undefined. The thyroid is said to contain mucine, particularly when in the state termed colloid degeneration; it then also contains cholesterine. When containing brown fluids, in the disease termed struma, a sediment of blood corpuscles is mostly present, which, however, contain only decomposed hematocrystalline in the form of hematine.

Suprarenal capsules.

These organs yield many curious coloured reactions. Their alcoholic or ethereal extracts become yellow and red when exposed to the air; their watery extracts are coloured red by iodine, and blackish blue by iron-chloride. They contain leucine, but the presence of other particular biliary matters which has been alleged is at present not proved. In certain chronic diseases (Addison's disease, or bronzed skin), in which the skin is more or less copper or brown-coloured, the suprarenal capsules are specifically diseased. A case of this disorder is now under special investigation.

Salivary glands.

The salivary glands contain mucine and leucine, xanthine and hypoxanthine.

Pancreas.

The pancreas contains much leucine, a homologue of it, xanthine hypoxanthine, and guanine. Also some of the ferments mentioned in the paragraph on digestion can be extracted from its pulp as well as from its juice.

Liver.

The liver consists of cells, which are the main seats of its specific function, and of bloodvessels and bile ducts, interspersed with lymph vessels and nerves. The blood can be washed out by water. The cells are made up of a protoplasma, which may contain as visible ingredients fat in large and small granules, cholophæine in small red granules, nuclei, with one or two corpuscles, and as invisible ingredients demonstrable by experiment only, a coagulable matter which sets soon after death, albumen, mucine, and glycogen. Sugar and biliary acids are also always obtained from the extract of the liver, although the ducts may have been carefully washed out; and as cholophæine is contained in the cells, we may assume that the bile acids are also contained and made in the cells. The fresh liver is always alkaline, but on standing it becomes acid. The glycogen is mostly or entirely transformed into sugar. The liver-extract by boiling water mostly contains lactic acid and volatile fatty acids, inosite, hypoxanthine, xanthine, and uric acid, and leucine. The latter body occurs in livers which are quite fresh, in very small quantity, but increases by decomposition, for which the tissue of the liver or its cells possess particular aptitude. Fat is extracted from most livers, in large quantities from diseased livers. Tyroine occurs in diseased livers only, and is not easily obtained even from thoroughly putrid livers. In the ash of the liver phosphoric acid and potassium predominate, which is the more to be noted as the bile acids in man are mainly combined with sodium. From fresh livers of young persons and animals hydrogen is sometimes evolved on immersion in warm water. The degeneration of the liver, which is sometimes wrongly called amyloid, or otherwise the "Speck-leber" of the Germans, and "waxy degeneration" of the English, has not any resemblance to the amyloid degeneration of the spinal marrow: for iodine and sulphuric acid, or iodine alone, produce in it only a red or reddish-brown mahogany-like coloration, its material being evidently of an albuminous kind: and on extraction by alcohol and ether, I have found in it considerable quantities of cholesterine, fat, and paralbumen, but neither bile nor sugar. Having during many years, and in many cases, observed considerable quantities of leucine in the liver, and having frequently experienced great difficulty in

Waxy liver.

Leucine, special method for isolation.

isolating this substance, separating it from others, I subjected to a special study the compounds of leucine with metals, and was happy enough to discover a new copper compound which renders leucine entirely insoluble in water and neutral fluids. For the extraction of hypoxanthine and xanthine I have also devised special processes.

Kidneys.

The kidneys contain much blood, collagene fibres, and some fat; to water extraction they yield chlorrhodinic acid, uric acid, and bodies resembling hypoxanthine and xanthine, but urea is scarcely obtainable from them. Cystine and inosite have on some rare occasions been met with. The chemical changes of the kidneys in diseases have not yet been sufficiently examined.

The urine.

The urine is the secretion of the kidneys. It is the lixiviated refuse from the chemical processes of the body. It contains a yellow colouring matter, urochrome, which by chemolysis yields various remarkable products of decomposition. The first is uromelanine, $\mathfrak{C}_{36} H_{43} N_7 \mathfrak{O}_{10}$, a most interesting substance, with an atomic weight of 733, being one of the highest at present established in organic chemistry. Accompanying uromelanine there is a small quantity of a matter which by treatment with sulphuric acid yields the reaction and spectrum of cruentine, termed paramelanine. The next product is uropittine, not as yet sufficiently studied. Then there is omicholine, an organic base with fluorescent properties and a peculiar spectrum, and omicholic acid, also fluorescent, but slightly differing in its spectrum and composition from omicholine. Of these matters I shall have to speak in subsequent paragraphs. From these products it is evident that urochrome must possess a very high atomic weight; it may perhaps be a derivate of hematocrystalline. The ingredient which occurs in urine in the largest quantity is urea, $\mathfrak{C} H_4 N_2 \mathfrak{O}$, of which a man secretes about 30 grammes in 24 hours. Then there is creatinine $\mathfrak{C}_4 H_7 N_3 \mathfrak{O}$ the same as that which occurs in the muscles. It is partly changed into creatine, $\mathfrak{C}_4 H_9 N_3 \mathfrak{O}_2$, by taking up an atom of water during the process of preparation. From creatinine is derived sarkosine, which is isomeric, or perhaps identical with alanine $\mathfrak{C}_3 H_7 N \mathfrak{O}_2$. There is further contained in urine uric acid, $\mathfrak{C}_5 H_4 N_4 \mathfrak{O}_3$, which may form calculi and cause much trouble, and a series of bodies being less oxydised than uric acid, namely, guanine, $\mathfrak{C}_5 H_5 N_5 \mathfrak{O}$, hypoxanthine $\mathfrak{C}_5 H_4 N_4 \mathfrak{O}$, and xanthine $\mathfrak{C}_5 H_4 N_4 \mathfrak{O}_2$. Further, there is an acid which from having been first discovered in horses' urine is termed hippuric, $\mathfrak{C}_9 H_9 N \mathfrak{O}_3$, remarkable by its consisting of a combination of glycocoll, $\mathfrak{C}_2 H_5 N \mathfrak{O}_2$, and benzoic acid, and by its being found in considerable quantity in the human body when benzoic acid is being taken, or greengages are consumed. Under some circumstances allantoine appears, $\mathfrak{C}_4 H_6 N \mathfrak{O}_3$, which can also be produced from uric acid artificially, along with other remarkable products. Of inorganic salts the phosphates of lime and magnesia, and of potash, are present in considerable quantity, but most prevalent is the sodium-chloride or common salt. Of some matters minute traces appear in the urine, thus of sugar and of alcohol, after these bodies have been taken by deglutition. In diseases there may appear blood, albumen, fibrine (paraglobuline and fibrino-plastic matter) fatty acids and fats, large quantities of sugar, as in diabetes, leucine, tyroine, abnormal coloured matters yielding by acids urocyanine and urorubine, as in cholera; oxalic acid and oxalate of lime, as in a particular disease which frequently ends in the formation of calculi. Much as the urine has been studied its chemistry is by no means accomplished,

Uromelanine.

Uropittine.

Omicholine.

Omicholic acid.

Urea.

Creatinine and creatine.

Sarkosine.

Uric acid group.

Hippuric acid.

Allantoine.

Salts.

Sugar, alcohol.

Pathological ingredients.

and on the causes of the most troublesome diseases showing themselves by symptoms in the urine, gout, uric acid calculus, oxalic diathesis, diabetes, chylous urine, our knowledge is as yet very incomplete.

Under all circumstances, however, the analysis of the urine is an indispensable aid to clinical diagnosis, and furnishes most valuable positive and negative information on acute as well as chronic diseases.

Sweat.

Lactic and sudoric acid.

The secretion of the skin, discharged in large quantities after exertion or under the influence of a heated atmosphere, contains much surface epithelium. Of chemical ingredients there are observed lactic and sudoric acid, the latter peculiar to sweat and not found anywhere else, and urea. There is much sodium-chloride, little or no phosphate. Sometimes volatile fatty acids–*e.g.* valerianic, are found in small quantity, but it is possible that they are formed after the sweat has been secreted.

Breath.

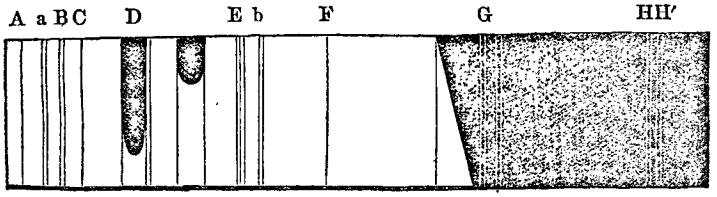
In respiration oxygen of the air inhaled together with its nitrogen is absorbed by the blood, and in exchange carbonic acid and water are given out. The expired air therefore contains less oxygen than the inspired, and a quantity of carbonic acid instead. But the whole of the oxygen inhaled does not return as carbonic acid and water ; a portion is otherwise combined and leaves the body in the urinary products of oxydation, particularly urea. A healthy strong man exhales in 24 hours upwards of 400 litres of carbonic acid, and inhales upwards of 500 litres of oxygen. The expired air during rest contains about four volumes per cent. of carbonic acid. During activity the expiration of carbonic acid becomes much more rapid, and in extreme cases may for a short time rise to tenfold its normal quantity in the same time. Activity or muscular work does on the other hand hardly increase the quantity of urea excreted by a man.

The breath in diseases may contain carburetted hydrogen (of which a trace is also excreted in health) and volatile matters at present unknown, ammonia being perhaps amongst them. These investigations have only just become possible by the invention of an apparatus which permits entire persons to be observed for days in glass chambers, and their excretions to be accurately analysed and determined. By means of this method it has now been found that man during sleep stores up a quantity of oxygen in his body, particularly his muscles, which is therefore ready for the production of force the moment it may be wanted. This explains the phenomena of activity and rest much better than they could hitherto be defined.

Fæces.

The fæces contain all insoluble residues of the food, some decomposed and altered bile acid, changed cholophæine, myochrome, cholesterine changed into excretine, some peculiar fatty and odoriferous matters, besides a little phosphate of magnesium and calcium. They vary with the diet, being dark, semifluid, and of small bulk after meat diet, but of large bulk, paler and more solid, after bread diet. Boiled with sulphuric acid they yield a matter which has the spectrum represented in fig. 1, plate III., and of which the accompanying engraving is a diagram.

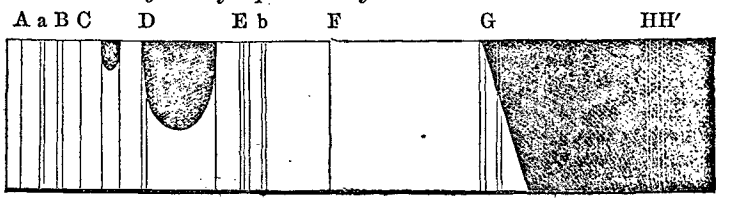
Stercorine in Sulphuric Acid.



Their anomalies are still less known than their normal composition. The cholera evacuations were fully described in my report on cholera,

But I here insert an amended diagram of their spectrum, which may be compared with stercorine on the one, and acid cruentine on the other hand.

Diagram of Spectrum of Fermented Cholera Stool.



Iron preparations taken into the stomach colour the fæces black, mercurial ones green. This latter fact gave rise to a fallacy now exploded, namely, that mercury was a cholagogue and increased the excretion of bile. Bile (not decomposed) has never yet been found in any fæces. Most remarkable and suggestive is the discovery by Liebig of alloxan in the mucous evacuations from a case of intestinal catarrh. Alloxan is a product of decomposition by oxydants of uric acid, and precedes the formation of urea. Possibly, therefore, functions of chemolysis are allotted to the intestine which at present we place into other organs, or know not where to localise. Gout might find an explanation in the failure of this chemolytic action, for uric acid once in the blood seems as far out of the reach of oxygen as sugar in the blood is in diabetes. Imperfect digestion further causes the production of gases, of which carbonic acid constitutes the main bulk, but is mixed with combustible marsh-gas, $\mathfrak{C}\,H_4$, and some hydrothion $\mathfrak{S}\,H_2$. This development in diseases rises to painful height, and in typhus, *e.g.*, produces sometimes an almost suffocating tympanites or meteorismus.

Alloxan in mucous evacuations.

Gases in intestines.

III.—ILLUSTRATIONS OF THE TENTATIVE NATURE OF THE RESEARCHES.

For reasons which need not here be detailed I began the present series of investigations by some inquires concerning Tetanus. The descriptions of this disease which had been given by surgical writers represented it as so much resembling poisoning by strychnia, that one was almost compelled to suppose that in its progress a chemical decomposition took place by which a body being either strychnia itself, or having almost identical properties in relation to the human frame, was developed, and I therefore put the question whether this body could be extracted from the organs of persons who had died from tetanus. I made extracts from a great variety of organs from the bodies of six patients who had successively died of that disease. In none of the cases was any strychnia met with; but what was as singular was, that although these persons had up to the time of death been taking large doses of morphia, partly by injection underneath their skin, partly by deglutition, none of their organs showed any sign of the morphia taken.* But from all the organs, and from the blood, matters were always extracted of which some appeared to possess the qualities of known substances, while others manifested themselves by new properties as bodies hitherto unknown. It now became necessary to identify those bodies which appeared to be known.

Tetanus.

* The slight solubility of morphia in ether, amounting almost to insolubility, was of course considered, and the processes and reactions were accordingly modified.

Cerebric acid.

Most important among them appeared a substance having many of the properties of a well-defined substance obtained from the brain, namely, cerebric acid. In view of the circumstance that tetanus had always been referred to a lesion of the nerve system, suspicion arose that the presence of this brain-acid might be a sign of the decomposition of nervous substance in consequence of which a product of that decomposition was distributed through the body. But as the question had never been asked whether this matter was not also distributed through a healthy body, this question had to be answered before any conclusion could be drawn from the presence of this substance in the other case.

Cerebric acid present in organs and blood corpuscles.

A research was therefore made on the occurrence of cerebric acid in various parts of the healthy body, and it was found to be almost universally present. By means of a research on a large scale concerning the chemistry of the blood corpuscles, it was ascertained that cerebric acid was also an unfailing essential constituent of the blood corpuscles. When, in continuation of the research on tetanus, the brains of the victims of the disease were subjected to chemical examination, and the results compared with the ordinary teaching of science, it was found that that teaching was either erroneous or incomplete. Even the existence of cerebric acid, which had been discovered by Frémy, had been disputed by Liebreich; and the researches of Liebreich had been controverted just a few months before by Köhler, who had spent no less a time than three years over his subject. It was therefore necessary for me to institute for my own guidance some preliminary experiments on the question of the constitution of the brain matter. Those preliminary researches are far from complete, but every step of them has yielded a reliable and new result, confirming in the main the teaching of Frémy, and establishing that between Liebreich's protagon and Frémy's cerebric acid the difference is more in name than in substance. I found, however, also, that none of these observers had even touched the question of the constitution of the brain matter; and that there was in this latter a nucleus of power holding together a chemical molecule of immense size which could not be separated by any of the re-agents employed by former observers. I therefore proceeded to split up this molecule by the process of chemolysis. By this research it was found that the brain matter yields all the substances described by Gobley, the cerebric acid of Frémy, the protagon of Liebreich, leucine, tyroine, a number of volatile alkalies—among them trimethylamine, three fluorescent bodies and an amorphous acid to be alluded to in the chapter on the albuminous substances, and to be more fully investigated hereafter; and, beyond that, left a residue which resisted even the chemolytical process, hitherto supposed to split up all animal matter. Thus it was clear that brain matter possesses a constitution which is of the utmost complication, and that means must be found to determine the size of its chemical molecule, and that these means cannot be exclusively the process of chemolysis, and subsequent calculation by synthesis of the results, but that it must be of a more direct kind.

Researches of Frémy, Liebreich, and Köhler.

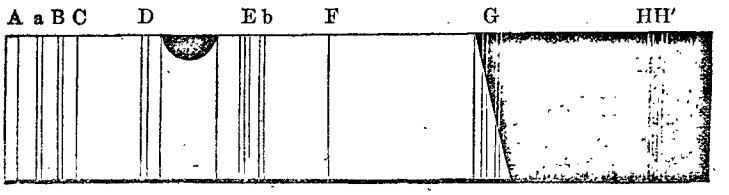
Chemolysis applied to brain matter.

These researches left me the impression that the constitution of brain matter possesses some analogy to the constitution of the blood corpuscles, in this respect, that its basis is a body which contains phosphorus, nitrogen, carbon, hydrogen, and oxygen, and may be transformed into or appear in the shape of cerebric acid; that this body possesses originally the properties of a polydynamic alcohol, which is combined with a number of molecules of albumen corresponding to the number of its dynamicities.

Returning to the comparison of the matter found in tetanous organs with that produced from healthy brains, I ascertained some new and

characteristic tests for that matter. Cerebric acid with sugar and sulphuric acid yields a magnificent purple colour, which is in every respect more striking than the colour which, with similar re-agents, is given by the biliary acids. I determined the spectrum (see Plate III. fig. 5) of the coloured product, and compared it with the spectrum of the coloured product obtained by this reaction from bile acids, and found them not to be identical.*

Cerebric Acid and Pettenkofer's Test.



Fluorescent bodies.

On continued scrutiny of the extracts obtained from the tetanous organs, substances were found which possessed the remarkable property of *fluorescence*. This was the more interesting as it had lately been announced by Drs. Dupré and Bence Jones that there occurred in all healthy structures a fluorescent matter to which, from its similarity to quinine, they gave the name of "animal quinoidine." The matter extracted from tetanous organs did not respond to the tests of animal quinoidine; although, behaving as an organic base, its optical properties were different from animal quinoidine, with genuine specimens of which it was assiduously compared. Owing to the small quantity of this substance, and to a deplorable accident which occurred to even that small quantity by an incipient conflagration in the laboratory, the nature of this substance had to be left undecided.

Fluorescent substance not found in a case of paraplegia.

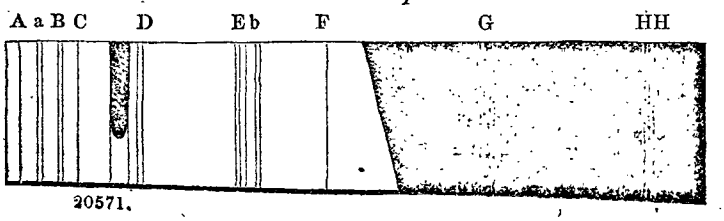
On examining, for the purposes of comparison, the organs from a case of paraplegia, the fluorescent body could not be met with. The cerebric acid was found in the blood and other organs, and, for the rest, it was clear that in this case the lesion was a mechanical one—that chemical consequences were secondary, and the study was therefore not prosecuted any farther.

Fluorescent matter in cholera extracts.

After the completion of the research on cholera (published in the last report of the medical officer), the whole of the extracts from upwards of a hundred organs, from more than twenty different cases, from which the matters described in that report had been extracted, were united. They were found to contain considerable quantities of the peculiar fluorescent matter which had been first met with in tetanus. As the investigation of the whole process of cholera had led to the discovery that there was, at one period of it at all events, a decomposition of

* Vitelline from yelks of eggs with sulphuric acid alone yields a spectrum which differs somewhat from that of cerebric acid. It is here subjoined. See also Plate III. fig. 4.

Vitelline in Sulphuric Acid.



albuminous substances in the intestine, very similar to putrefaction, as evidenced by the presence of leucine, valerianic acid, butyric acid, acetic acid, volatile alkalies, and so forth, I was led to surmise that the presence of this fluorescent body in the tissues might possibly be caused by the putrefactive decomposition, and that, inversely, the presence of that body might be the sign of the presence of a change akin to putrefaction. It therefore was necessary to subject to an examination in this respect the normal substances which constitute the tissues and fluids of the human body; and I selected, in the first instance, the process of chemolysis as the quickest and most suitable. I instituted an extensive research on the chemolysis of fibrin, albumen, caseine, blood, and almost every tissue and organ of the human body, the main features and results of which will be described in chapter V.; and I obtained not only products which had been obtained by former observers since Braconnot and by my own former researches, but I also was fortunate enough to isolate six compounds, a portion of which were quite unknown hitherto, and another portion, though known, not having been hitherto discovered in the course of this process. Among them was the fluorescent body which I had met with in the extracts from tetanus.

New compounds obtained by chemolysis of albuminous bodies.

Products of chemolysis.

I state here the conclusion at which I at once arrived, and which I do not think can be questioned by the calmest consideration. Whether the fluorescent body extracted from tetanus-organs, and which is probably the same as that obtained by chemolysis from albuminous matters, including the brain, has any causative influence in the production of the tetanic symptoms, or is itself a mere symptom or accident of the process, a practical advance can be made upon the theory of tetanus by the study of the fluorescentine obtained by chemolysis. The continuation of these researches, being contingent upon the occurrence of cases in an available form, is for the time interrupted. No doubt in other cases other questions may arise, and many of them are as present to my mind as those which I have already endeavoured to answer. That there is in tetanus the most rapid change which occurs in any disease whatever is shown by the enormously high temperature which we observe in that disease. In no other disease does the body reach the temperature of 44 degrees centigrade; and in those diseases in which we observe the next high temperatures, namely, typhus fever, typhoid fever, yellow fever, and others, the limit of 42 degrees is never exceeded without fatal results.

Hydrophobia.

The next disease almost as fatal as tetanus, which engaged my attention, was hydrophobia. I instituted a microscopical examination of the spinal cord of some cases, according to the latest and most approved methods, without finding any lesion perceptible by the microscope. On turning my attention to the blood, I was struck by a slight change in the spectrum; but it was impossible in the then state of affairs, and with that low degree of perfection in the measuring apparatus of the spectroscope, to give to that observation a scientific precision. It led me, however, to a comparison of the red coloured part of the blood with the red coloured part of the muscles; and as both in tetanus and hydrophobia the muscles are the field upon which the symptoms are most prominently exhibited, it appeared a fair question whether in either of those diseases there is an influence exercised by the blood upon the muscular system, or, inversely, by the muscular system upon the blood. The same question occurred during the cholera inquiry, when in cases of collapse and so-called asphyxia the muscular system was found of a dark, almost bluish-colour, and yielded a spectrum of reduced cruorine. It was in the interval between the cholera research and the former researches on the diseases mentioned that I discovered the

identity of cruorine and myochrome, the red coloured matter of the muscles. The physiological and pathological conclusions to which this newly-discovered relation led were very many and of immense bearing, for it was now established that neither of those two systems, the blood and the muscles, could escape the effect of the injury of either.

Typhoid and other febrile processes; their effect upon the muscles.

The loss of muscular power in the febrile process must clearly in part be the result of want of oxygen. For the peculiar products of the typhoid process for example, have a great affinity for oxygen, and circulating in the blood, abstract the oxygen for their own destruction before it has had time to reach the tissues. A muscle in typhoid fever is therefore in the same condition as a joint of meat hung up in an enclosed space without any ventilation. It was seen that gases which killed or injured by a specific effect upon hematocrystalline, such as carbonic oxyde, carbonic acid, sulphuretted hydrogen, and hydrocyanic acid, exercised their effect not only upon the blood but also upon all the muscles which are pervaded by blood, particularly the heart; and it became possible to suppose, in the case of cholera in particular, that the contraction of muscles, the painful cramps, were the result of diminished or altogether suspended oxidation. The most important change of the muscular system which takes place in typhus and typhoid fevers being regularly accompanied by a change of the natural colour of the muscle, I thought it necessary to make a research into the chemical nature of cruorine and myochrome. I began with cruorine. I precipitated it from blood on a large scale by means of carbonate of potash, and split it up into its constituents, albumen and hematine. I crystallized it in various ways, and compared its forms and phenomena of crystallization with those of its decomposition product hematine. I studied its spectra under the influence of a great variety of agents, medicines, poisons, and destructive bodies, and compared those spectra with a great number of spectra selected at random from similarly coloured bodies. I endeavoured to determine its atomic weight, and found it to be the highest of any among organic substances, and to amount to about 13,000. I then proceeded to investigate the phenomena of the crystallization of hematine. This latter is a product of the decomposition which blood undergoes not only by artificial chemical means, but also under the influence of physiological agencies when blood has been effused into cavities or tissues of the body. The crystallized hematine there found by means of the microscope has received the name of hematoidine. The crystallized compound, however, which was obtained from blood by a process employing acetic acid and common salt has been called hemine. It had been alleged that hematoidine was identical with the colouring matter of bile, and that the production of these hematoidine crystals in apoplectic cysts, in effusions of blood within the liver, and various effusions of blood in other organs—for example, the ovary, was evidence of the derivation from the colouring matter of blood of the colouring matter of bile. It had further been taught that hemine was not crystallized hematine merely, but a hydrochloric acid salt. Nothing could solve all these contradictory statements but an exhaustive research on the chemical nature of hematine. This I accordingly began, and was soon successful in obtaining a crystallized product having all the appearances of hemine, but not containing any hydrochloric acid, and yielding a little more than 7 per cent of metallic iron, thus indicating that the atomic weight of the hematine was upwards of 600. The spectra of hematine and of its products of decomposition by acids and alkalies were simultaneously determined. (See Chapter IV. 2. where most of the data evolved by this research are given.).

Hematine.

Hematoidine.

Hemine.

APPENDIX.

No. 7. *On Chemical Identification of Diseases, by Dr. Thudichum.*

Spectra of cholera urine.

This research was of the utmost consequence in the explanation of some new phenomena which were observed upon choleraic urine. It will there be seen that an ingredient of the urine was discovered which, under the influence of nitric acid, was transformed into a blue matter, choleraic urocyanine, and into choleraic urorubine, and the spectrum of this latter almost completely coincides with the spectrum of hematine in alkaline alcoholic solution. Further researches will have to decide whether this apparent analogy can be allowed to be assumed as a proof of close connexion. There can be no doubt that the spectrometric method applied to this branch of the research will yet lead to most important developments.

Cholophaeine.

I had an opportunity of comparing hematoidine crystals with crystals of the colouring matter of bile which I obtained in my researches on that substance incidental on my researches on gall-stones. I thought it incumbent on me to follow out this subject farther. The colouring matter of bile seemed to require an independent study, on account of the important part which it takes in many acute fevers, accompanied by the discoloration of the surface of the body, and particularly in malignant acute jaundice or atrophy of the liver, and in the chronic diseases of that name. Moreover, it was a common ingredient of concretions, the nature of which I had investigated formerly, and I therefore proceeded to investigate its nature. I succeeded in determining its form of crystallization, and in showing that it was not identical with that of hematoidine. I determined its chemical composition to be $C_9 H_9 N O_2$. I determined its atomic weight, its properties, its transformations, and a great number of its compounds, and it was owing to my former researches upon this substance, and the circumstance that I had a collection of material at hand, that I was enabled to give to the research upon this subject that perfection which I should claim for every other substance which is to be considered in pathological chemistry. A full technical account of this research would not be entirely suitable for the present report; but in Chap. VI. (on the biliary substances) I have given a full abstract of the principal data.

General remarks on coloured ingredients.

The circumstance that hematocrystalline and certain ingredients of the bile and urine are coloured may with some persons have the effect of hiding their chemical and general importance; for as in general life colour is employed for ornamentation, and is not considered necessary for the essential qualities of things, the ordinary mind is liable to suppose that these coloured ingredients of secretions or fluids are also of no greater significance than dyes. But this is a great mistake. The circumstance that they are coloured is of advantage to science, inasmuch as the presence of such bodies has not to be discovered. They are patent to every eye; but the circumstance that they are coloured, and that with every change, even the smallest, of their composition they change their colour—to wit, the blood from light red in the arteries to dark red or blue in the veins—shows that colour here is associated with an essential property, the significance of which is a subject for the deepest study. The usefulness of this study on the colouring matter of bile appeared very strikingly during the research on cholera which has been published.

Reference to bile in cholera.

Here a number of biles from persons who had died of cholera were examined. Several of them were found free from all coloured matters. Several of them were found not to contain any biliary acids. One at least contained no biliary acids but coloured matters, and these coloured matters varied in several cases. There were present the four varieties, bilirubine, biliverdine, biliprasine, and bilifuscine. Now, whatever may be the significance of the presence or absence of these or other

ingredients of the bile in these cases, it is certain that the facts could not have been determined had not the chemical nature of the substances and their chemical reactions been previously determined by me.

Incidentally I may remark here that by attentive study of the records concerning yellow fever, and by personal experience concerning some forms of tropical disease in Europeans, I have come to the conclusion that the coloration of the skin experienced in those diseases is probably not caused by biliary matter distributed in the blood, but is due to decomposition of cruorine yielding products of which I may have to speak hereafter.

Hematocrystalline decomposes in yellow fever and tropical fever.

During my investigations of the phenomena of the febrile process, I was struck with the small amount of positive information which was yielded by an analysis of the urine. Beyond an increase in the quantity of urea discharged in given times, and a diminution of the urinary water, no particular fluctuations in the quantity of the substances were observed, except the phenomenon known from time immemorial, that the febrile urine has a dark red, sometimes almost brown colour, and deposits matters which carry down with them a certain amount of those colours. The controversy regarding these matters has lasted as long as the research on them, until at last accomplished physicians have declared that these were matters not admitting of accurate chemical definition. I never shared that belief, and I continued to work through all difficulties, having at last the satisfaction of seeing my researches approved by the British Medical Association. The work then begun had now to be continued, and if possible completed, for without the knowledge of these matters a perfect theory of any febrile process whatsoever was quite out of the question. I therefore instituted a research on a very large scale, which absorbed many months of my time, and of that of several of my assistants, and I succeeded in establishing by the method of chemolysis a certain basis from which the chemistry of urochrome can in the future be solved with certainty. This basis is uromelanine, a product of decomposition of urochrome by putrefaction, as well as by artificial decomposing processes. This remarkable substance was found to have the enormous atomic weight of 733, being the highest among any decomposition products of the animal economy or of organic matters in general known. It was found to have a remarkable and varying combining power, so that no less than 19 combinations could be produced and analysed. I have subjoined an abstract of the principal data evolved by this research to the paragraphs relating to researches on the pathology of the urine (Chap. VII.). Besides uromelanine, I also analysed omicholine and uropittine. Omicholine was found to possess optical phenomena being the reverse of those of the green coloring matter of leaves, chlorophyll, for it had a port wine red colour, and in the cone of concentrated sunlight it fluoresced green, while chlorophyll, with its natural green colour, fluoresces red in the cone of sunlight.

Febrile process, variation of, excretions during.

Omicholine and uropittine.

While the researches on hematine had made it very doubtful whether there existed any connexion between the colouring matter of the blood and that of bile, and had shown that the assertion of former observers that the colouring matter of bile contained iron was unfounded, the researches on urochrome seemed to confirm the conception which former observers had formed of this matter being derived from cruorine by some process or other. Uromelanine could not be derived from hematine, unless indeed all the analyses of hematine hitherto made were first shown to be valueless. The atomic weight of hematine, even if the formula of Mulder were doubled to satisfy the demands of the theory of

the unitary notation, could not be much above 600, that of uromelanine actually is 733; by no calculation can the number of atoms of nitrogen in hematine be raised above six, while uromelanine unquestionably contains seven; hematine might therefore derive from uromelanine, but the reverse could if hematine be rightly understood never be the case. We have therefore but two possible cases. Either all the analyses of hematine hitherto made must be rejected, and supplanted by new and better researches, or, if they can be maintained, we must assume that uromelanine derives from hematocrystalline and not from hematine. From this it would further follow that hematocrystalline in its natural process of disintegration does not split up, as it does under the influence of acids and alkalies, into hematine and albuminous matter, but is by gradual oxydation transformed into an intermediate substance, which by the specific action of the kidneys is eliminated in the form of urochrome. Urochrome then would be hematocrystalline reduced to the limits of oxydisability and effete; of the great mass of albuminous substance only feeble traces are left in the shape of the nuclei, which after chemolysis appear as omicholine and uropittine. The great mass of what would have become hematine under appropriate conditions leaves the body in the form of the nucleus, which by chemolysis becomes uromelanine. The probable atomic weight of urochrome, which by the synthesis of its cleavage products is raised to about 1,500, fully supports these theoretical considerations.

IV. THE SPECTROSCOPE AND ITS APPLICATION IN PATHOLOGICAL CHEMISTRY.

1. *Generally, of the Spectroscope and its Uses.*

Origin of spectral observation. Prism a toy.

A triangular rod of glass has at all historical times been a toy in the use of which mankind delighted. For it was and is now the only generally applicable means by which the eye can at will enjoy the sensation of pure colours. Only two phenomena of nature offer opportunities for the same observation, the glorious rainbow and the polar aurora; the latter as awful as the former is consoling to the inhabitant of the moderate zone. The identity of the rainbow colours with those of the glass prism did not escape the eye of Seneca; and Vitellio, observing the same colours upon the rays of light which had passed through a glass of water, even made an unsuccessful attempt at their explanation. After Aristotle had shown the production of the rainbow colours upon a screen, this experiment remained for two thousand years a part of the scanty optical knowledge of philosophers. When Porta invented the dark chamber or "camera obscura," he facilitated the spectral observation greatly, and caused Kepler to attempt a long commentary upon it. Grimaldi discovered the elongation which the image experiences when the spectrum is formed. Marcus Marci was perhaps the first to describe the principal experiment with the glass prism in his "Thaumantias," but he arrived no closer to its actual theory than Ruini or Servetus to that of the circulation of the blood.

Spectrum projected on a screen. In "camera obscura." Elongation of image by prism.

Different refrangibility of light gives colours.

Newton founded the science of optics by showing the nature of simple colours, which he defined as light-rays of equal refrangibility. The difference of colours was therefore based upon the different refrangibility of light. These discoveries he applied to the explanation of the variation of colours, of the natural colours of bodies, and to the explanation of

the rainbow. With the perfection of apparatus rose the means and the desire for more accurate observation. While Newton had mostly used a ray of light which entered through a round hole and was then broken up by a glass prism, Wollaston contemplated the prismatic picture projected by a sun-ray which entered the dark room or camera through a narrow slit. He thereby purified the spectrum and discovered (1802) black lines in it. He gave a drawing of five lines, besides the two terminals of his spectrum. But this discovery remained unused until Fraunhofer made it once more and established it as a new means for measuring phenomena of light (1817). He used the telescope for the examination of the spectrum, and discovered a great number of lines, the principal ones of which he appointed as standards of measurement for the several places and parts of the spectrum. During the first half of this century following the discovery of Fraunhofer, many learned physicists, particularly Sir D. Brewster and Sir John Herschel, studied the phenomena which were caused by the substitution of glowing solids or gases as sources of light in place of the sunlight, and by the interposition of fluids and solids on the path of the sun-ray before it reaches the prism. (Positive and negative spectra. Effects of absorption of particular rays.) The data thereby ascertained were stated in physical handbooks, without particular practical inferences, until Kirchhoff and Bunsen (1859) based upon them a new research, which culminated in the establishment of a law of photolytic peculiarity of chemical elements, and in the explanation of the physical causation of Fraunhofer's lines as absorptions of light from the sun's nucleus effected by the metallic vapours of the sun's gaseous envelope. Practically this research effected an immense extension of the delicacy of chemical reactions, led to the discovery of several new elements by means of that extension, and to the discovery of their general distribution in the mineral, vegetable, and animal world. I augmented the means of studying the nature of the sun, and of the fixed stars, which Fraunhofer had already shown to differ optically from the sun. The nature of heat as connected with light had first been discussed by P. Prevost (1792) on the basis of his corpuscular theory. Kirchhoff now maintained the identity of heat and light by theoremata, and showed that heat and light are forms of motion of the ether, and that heat is moved ether vibrating invisibly in longer waves than the rays which correspond to the red beginning of the spectrum.

Sun-lines.

Many sun-lines discovered by telescope.

Positive and negative spectra.

Spectral analysis of earthly and celestial objects.

Heat a part of light.

It had often been observed that various solids and fluids had particular effects upon light. Thus fluor spar assumed a particular appearance when it reflected light; the colourless solution of quinine allowed all direct rays to pass, but appeared to reflect a blue part; green chlorophyll became blood red when throwing back the sun's rays. These phenomena were long studied by Sir D. Brewster and Sir John Herschel, until Stokes established their theory, now known by the name of fluorescence. The prismatic analysis of light was found to separate heat rays, coloured rays, and a third series of rays, extending on the violet side of the spectrum, which without special precautions were invisible to the eye, but could be made visible by the effect which they possessed of transforming the atoms of certain solids and fluids into self-lighting bodies, so that these substances when placed in these rays emitted a peculiar light, differing from the colour which they bore in diffuse daylight or lamplight. Or the fluorescent bodies have the power of transforming the movements of ether, which vibrates in short waves, into long wave-vibrations. This power belongs not only to the ultra-violet, ordinarily invisible rays, but also to the violet and blue rays of the ordinary sun and gaslight spectrum. It is therefore that particular kind of light which is chemically most active by effecting combination

Fluorescence.

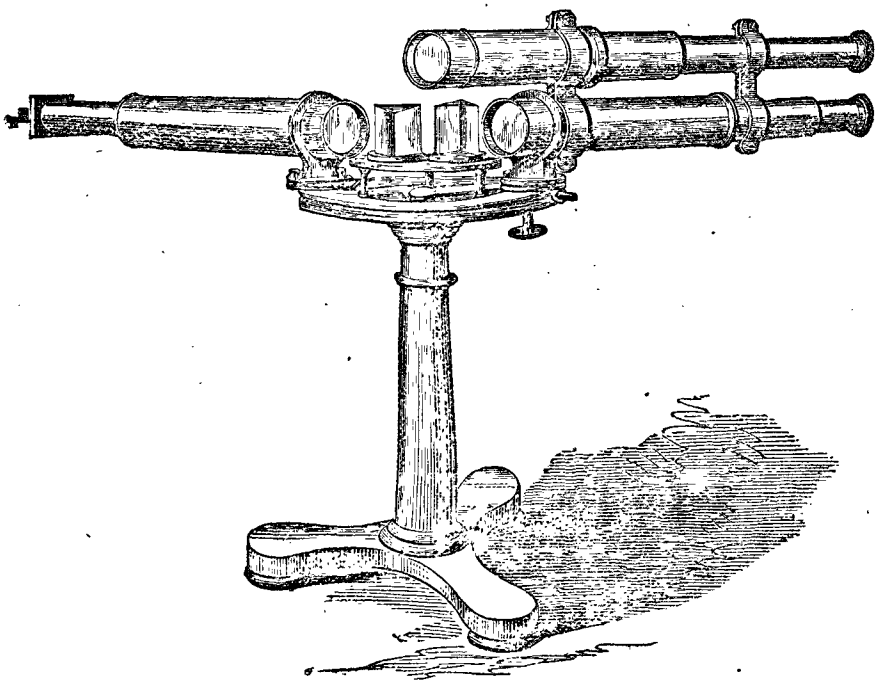
Chemically active rays.

Spectrometer, improvements of.

and decomposition of sensitive agents which also shows the greatest influence upon bodies having the power of fluorescence.

Improved Spectrometer.

In the cholera research I described the spectrometer which was then at my command, and the amount of accuracy obtainable therewith. Having since found the absolute necessity for greatly increasing the means of observation, I improved the spectrometer in the following way.



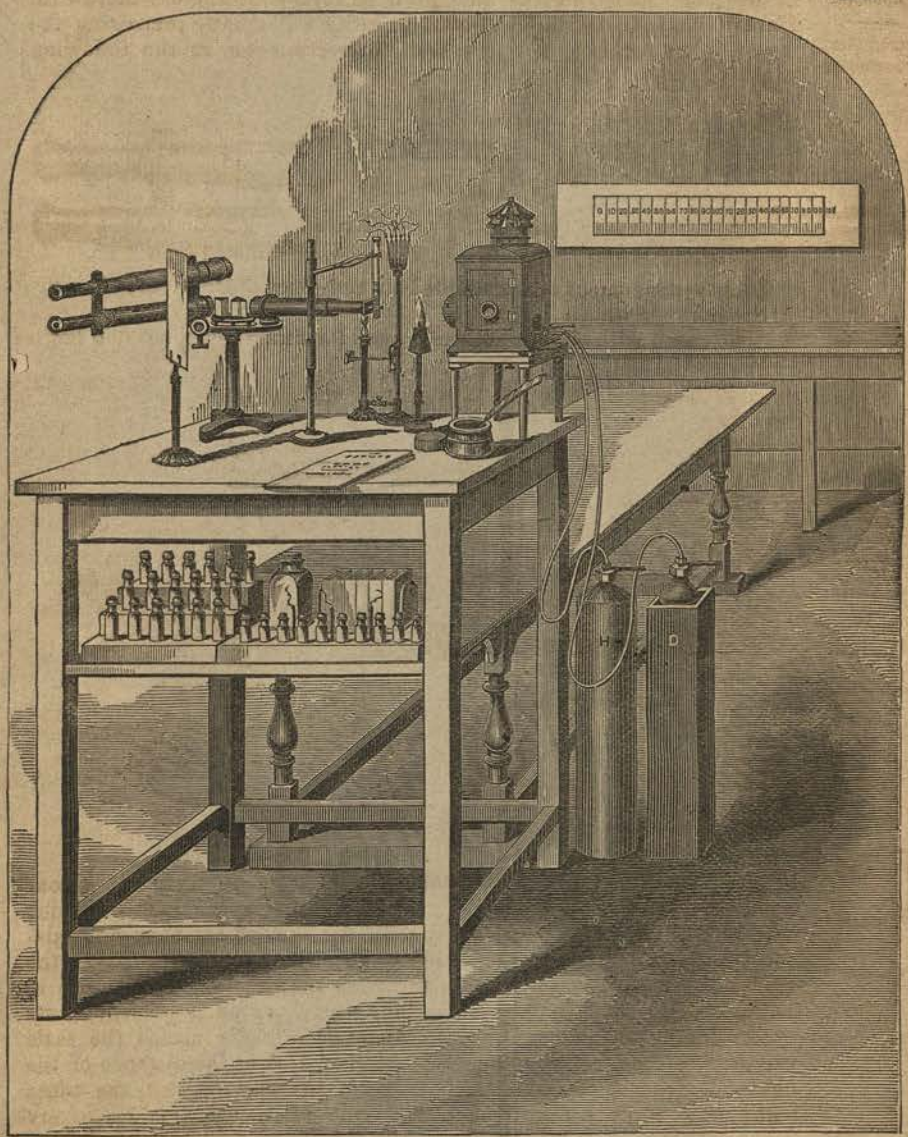
New Spectrometer.

Over the observing (astronomical) telescope I fixed a second (terrestrial) telescope of double magnifying power, the axis of which was parallel to and perpendicularly over the axis of the observing telescope. Both telescopes were provided with the usual wires across the field. At the distance of 15 feet from the observer a measure in large, bold, legible characters was put up, every point of which was observable by the adventitious telescope. By these means the scale originally observable by the nonius was increased as the distance of the new scale from the centre of the ring of the spectroscope, the effect being that while before I could read each of the 67 divisions of my entire spectrum, I could now observe and read 200 ; or, in other words, I increased the accuracy of my observations $4\frac{1}{2}$ fold. But by introducing a cross of spider's web into the telescope, it was possible to read tenths of each division, so that the apparatus now enables the observer to measure each of 2,000 divisions of the colour spectrum.

The accompanying engraving shows the ensemble of the arrangements

by means of which most of the following observations were made. The lantern on the right contains the arrangements for the production of Drummond's lime-light, which is supplied with oxygen and hydrogen from the reservoirs on the floor. These are iron bottles, in which the gas is contained under pressure.*

Subjoined are represented some of the details of the apparatus on the

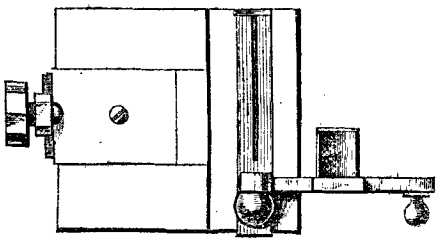


Spectroscopic Observatory.

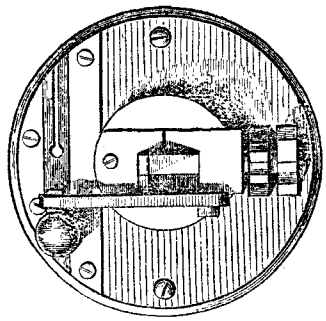
spectroscopic table. One is the slit instrument, with arrangements for widening or narrowing the slit by means of the screw on the left. The

* This very convenient form of apparatus is made by J. Orchard, optician, Kensington.

little prism on the right can be put before the slit, in order to make a second spectrum from another source of light appear above the primary one.



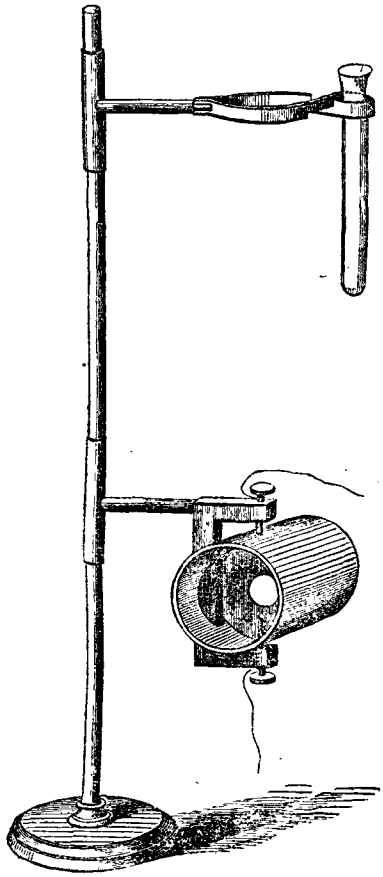
Slit Instrument.



Circular form of Slit Instrument, with the Reflecting Prism applied.

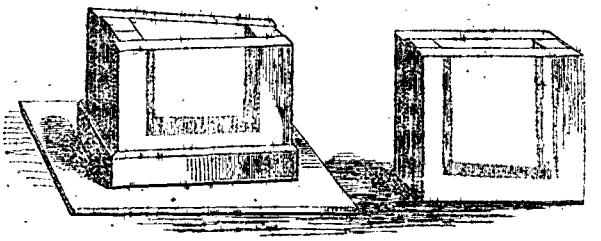
This arrangement is represented in the circular form of slit instrument here shown.

The stand with sliding holders is used for fixing test-tubes and bottles



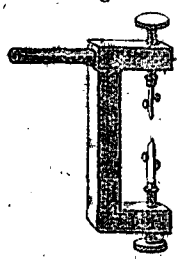
before the slit of the spectroscope. It is so arranged that for the spring clamp isolated ebonite holders can be substituted, to which the two

terminals of an electric battery and Rühmkorff coil are fastened. In the engraving the terminals are enclosed in a tube which carries a condenser. By this arrangement the eye is protected from the glare of the spark, and able to observe any fluorescence or positive spectral



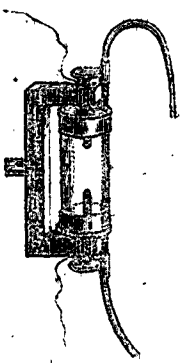
Troughs of Quartz for Fluorescence Observations.

phenomena, without interference. For the fluorescence observations, little troughs of quartz, as represented in the accompanying cuts are used. When the spectra of metals are to be observed by means of the spark, two pieces of wire of the metal to be observed are clamped in the little pincettes of the isolated ebonite instrument represented in the engraving, which can be fixed to the stand above figured. The observation, by means of the spectroscope, of the spark, which passes from one wire to the other, then yields the spectra of the metals of which the respective wires are composed, superposed upon the peculiar spectrum of the electrical light, and of the gases of the air heated by the spark.

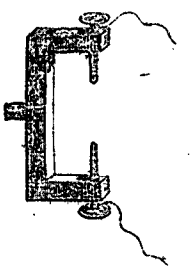


The influence of pure gases upon the spectra of the spark and of metals is ascertained by the comparison of the spectra which the spark gives in atmospheres of pure gas. For this purpose the poles are enclosed in a glass vessel, through which a current of the gas which it is desired to examine can be passed.

Influence of gases upon the electrical and metallic spectra.



Glass Vessel, Tubes, and Poles on Ebonite Isolator.

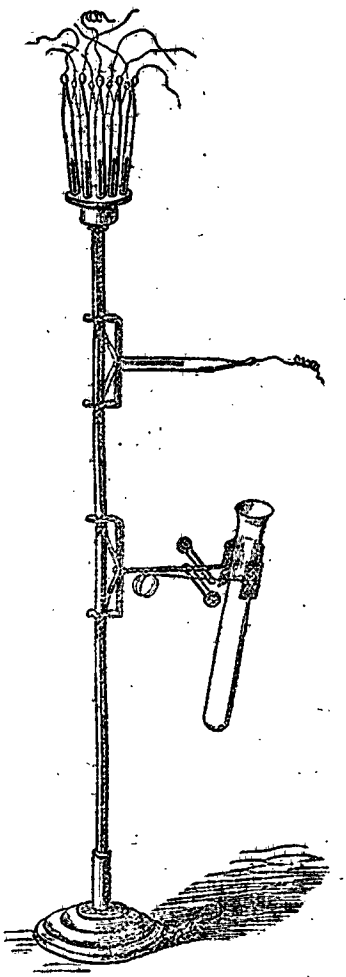


Poles on Ebonite Isolator, the Glass Vessel removed.

By the side of the stand and its isolating attachments described in the foregoing, the stand devised by Bunsen, and figured in the annexed wood-cut, is required. It carries a supply of platinum-wires fused in the

Bunsen's stand and bead-carrier.

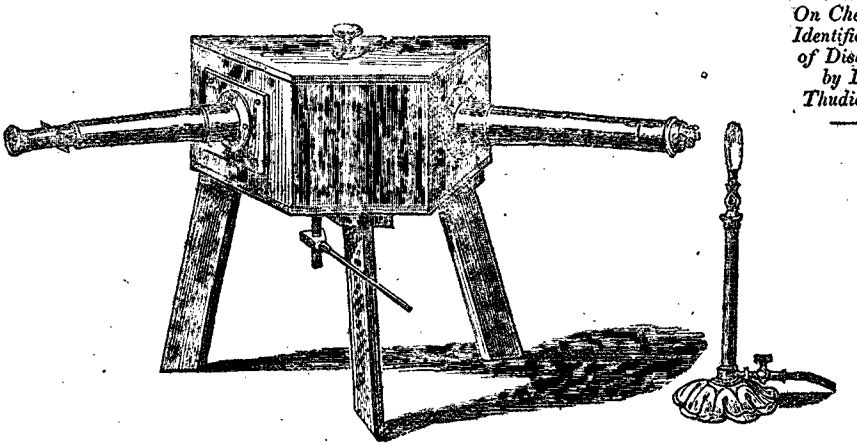
ends of glass tubes, ready for being dipped into the matter under examination, and for being introduced into the flame of Bunsen's burner by means of the upper spring-clamped arm of the stand. The lower spring-clamp is to carry test-tubes, in which substances under examination can be heated, or, after admixture of suitable agents, be deflagrated before the slit of the spectroscope.



Bunsen's Stand, Platinum-wire Bead, and Deflagration Tube-carrier.

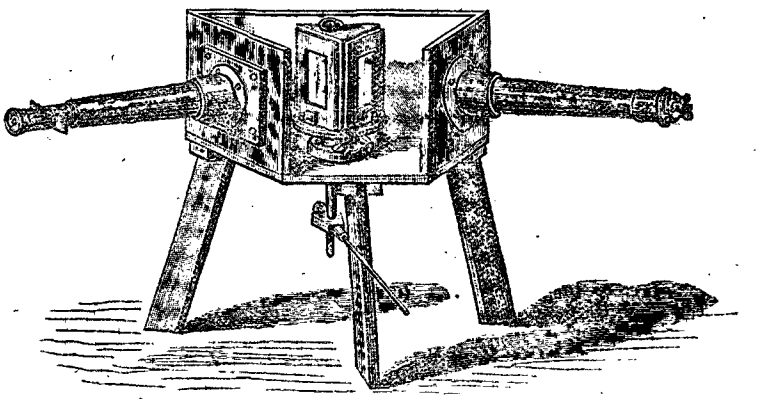
By the side of the foregoing spectroscope, I frequently had occasion to use two other spectroscopes. One was the instrument here represented. It is provided with a sulphide of carbon prism, which can be turned round its perpendicular axis by means of the turntable on which it stands, and to which the perpendicular rod and horizontal clamped lever are attached. The telescope-tube projecting on the right bears the circular slit instrument described and figured above, while the astronomical telescope on the left is provided with the sliding screens,

excogitated by Dr. A. Dupré, and represented in their actual size under the paragraph relating to the spectrum of sodium, which will be found



Spectroscope, as originally designed by Kirchhoff and Bunsen.

lower down. The internal arrangement of this spectroscope is well seen in the subjoined engraving. When in action, the two glass faces

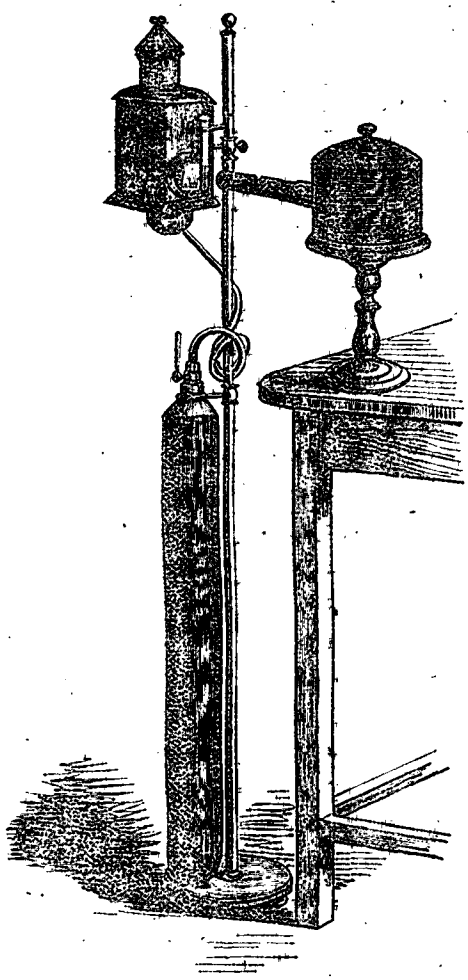


Sulphide of Carbon Prism and Turntable, in the original Spectroscope of Kirchhoff and Bunsen.

of the prism, here turned towards the spectator, are of course turned towards the back of the box.

This spectroscope is now generally abandoned, on account of the currents produced by heat, which easily disturb the refracting medium, and make the spectra inaccurate. This error is, however, evanescent when a common gaslight is used. In my researches I found this apparatus, and the still more simple spectroscope already described in my report on cholera, invaluable. For the turning of the prism admits of the lengthening and shortening at will and before the eye of the observer of any part of the spectrum, according to the position which the prism is made to assume with relation to the incident ray of light. By these movements faint absorptions can sometimes be discovered, which would not otherwise be perceived.

The most simple form of spectroscope is the one figured herewith. It shows the entire spectrum at one glance, and of great brilliancy when a sulphide of carbon prism of a refracting angle of 60° is used. By its



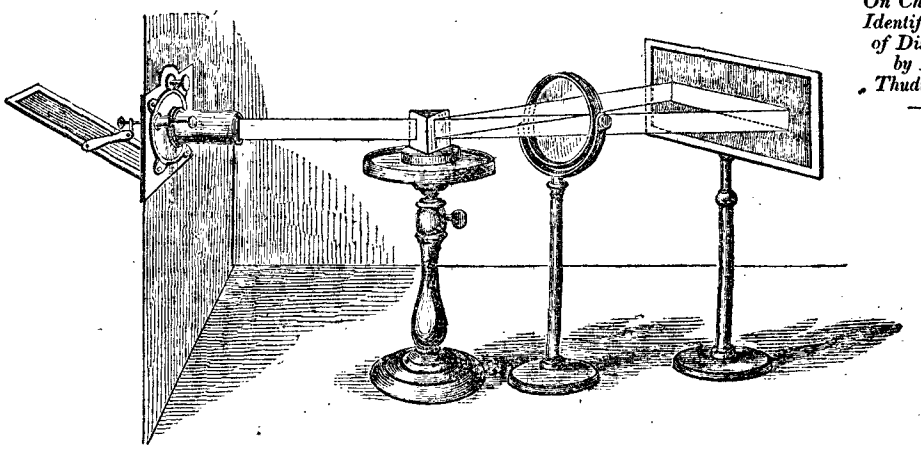
Simple non-magnifying Spectroscope and Medical Lantern, with the spirit-oxygen-lime-light.

instrumentality the fine absorption-lines of fluopittine, boviprasine, and five-banded hematine and cruentine, described in some of the following paragraphs, were discovered. It shows Fraunhofer's lines in diffuse daylight, and gives a good spectrum with any candle. In the absence of sun-light I use the medical lantern,* containing arrangements for the production of Drummond's light by means of spirit and oxygen.

The spectral phenomena, which cannot be investigated by means of the electric spark, and more particularly the phenomena of fluorescence,

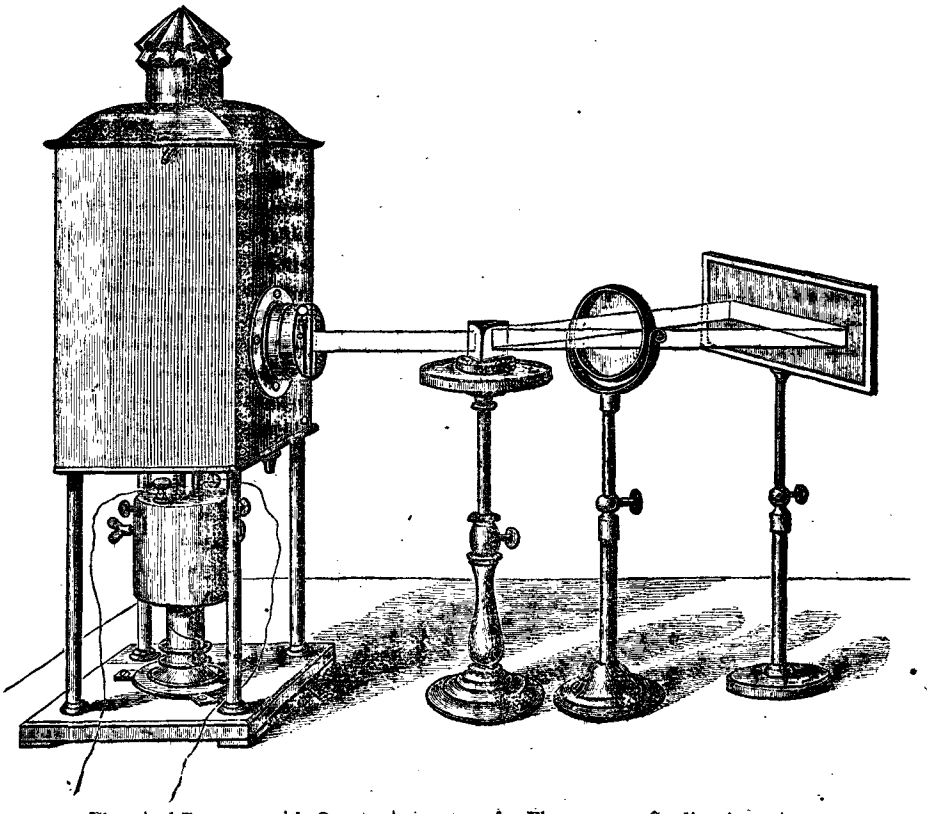
* I imagined this apparatus for the illumination of the nasal cavity, the pharynx and larynx, and other medical and surgical purposes. In respect of convenience, it is superior to any other light hitherto recommended, and in respect of power it is inferior only to reflected sun-light. It is manufactured by J. Orchard, optician, of Kensington.

have to be studied by means of sunlight, conducted into a room in the manner represented by the subjoined engraving, or an electrical lantern, supplied with quartz-lenses and prisms, and a battery power



from 30 to 40 large Grove's elements. The following engraving represents the arrangement which I use at the Pathological Laboratory, in action.

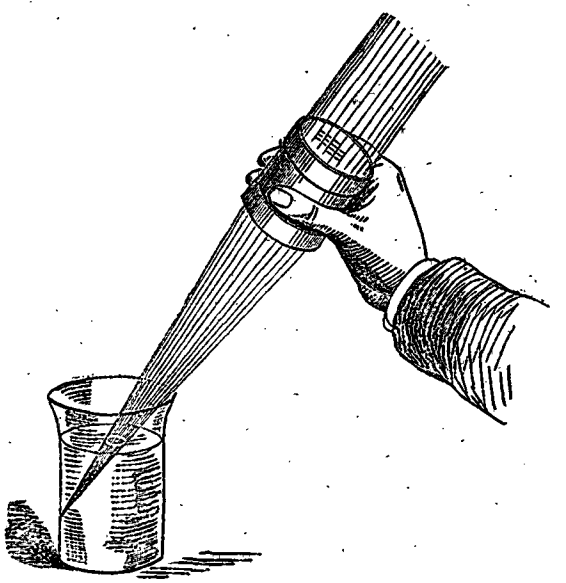
The reaction of fluorescence as a means for the identification of known substances and the discovery of new ones, is, under ordinary circumstances,



Electrical Lantern, with Quartz Apparatus, for Fluorescence Studies, in action.

best applied by means of a system of quartz lenses, which throw the light of the sun into the fluid directly without the intervention of any glass, in the manner represented in the subjoined engraving.

For ordinary purposes a common glass lens serves very well, and the intervention of the glass of windows or vessels is of no particular consequence. But for exact study all glass has to be removed, as it fluoresces itself in some degree, and consequently would absorb the rays which are able to produce fluorescence in fluids partly or entirely before they could have reached the fluids. In such examinations vessels



Mode of testing Fluids with respect to Fluoresence, by means of a Cone of Sunlight collected by a system of Quartz Lenses.

of quartz, of the shape of those above represented, but of much larger size, have to be used, which, like quartz lenses and prisms, allow the fluorescent rays to pass without perceptible absorption. The fluorescent cone should be inspected with a Nicol prism. If it be due to true fluorescence, it will remain unchanged when the Nicol is turned round its optical axis before the eye, but if it be caused by false fluorescence, that is to say, by the illumination of fine suspended particles, it will alternately become darker and lighter and of its original colour.

I must reserve for a future opportunity a fuller account of this magnificent method of investigation, the latest and fullest development of which we owe to Professor Stokes. I have used its elementary forms throughout my researches, and by its aid been able to identify many substances, and to discover at least five new bodies. Such are fluorescentine,—an organic alkaloid derived from albumen, which, being colourless, fluoresces with a violet colour; omicholine and omicholic acid, being red, and fluorescing with a green colour; a derivate of hematine, being red, and fluorescing with a grass-green colour; another derivate of hematine, fluorescing in its own red colour, a novel and most remarkable phenomenon. Omicholine and omicholic acid, and the green fluorescent derivate of hematine, exhibit the reversion of the phenomena of chlorophyll, which is green, and fluoresces blood-red. But the green fluorescence of the hematine derivate is particularly

remarkable on account of its bearing upon the so-called "dichroism" of hematine, or the property of certain of its solutions to appear green in thin, and red in thicker layers.

Application of the Spectroscope to the Discovery of Metals in Human Tissues and Fluids.

Metals in human body.

Metals occur in the human body as normal or abnormal ingredients. The normal ones are constantly present. Those which are certainly essential are potassium, sodium, calcium, magnesium, iron; those of which the presence is perhaps only accidental, though constant or at least only in substitution of sodium and potassium, are lithium, rubidium, caesium, copper, and manganese. Of abnormal ingredients we have two classes, innocuous and poisonous ones. To the former we class strontium, to the latter barium, and a series of the heavy metals, which may be medicines or poisons, or both, according to the quantity in which they are present in the body. Such metals are lead, tin, thallium, iridium, mercury, silver, antimony, arsenic, bismuth, nickel, zinc.

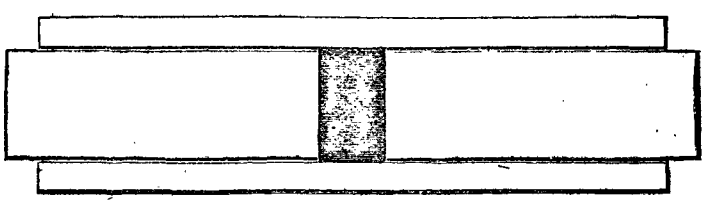
A considerable number of these metals may be recognized at once when a small piece of tissue is held in the flame of the colourless gas-burner, and the flame is analysed with the spectroscope. But it is preferable to first calcine the parts and fluids, after evaporation and drying in platinum vessels, lixiviate the ash with water, then with hydrochloric acid, ultimately with nitric acid, or if only ordinary metals are inquired for, with hydrochloric acid only.

The hydrochloric acid solution of the ash of the human body gives a splendid spectrum, the field of which shows many red, yellow, green, and blue lines in various parts of a dark field. By careful measurement it is found that these lines are peculiar to six metals—potassium, sodium, lithium, rubidium, caesium, and calcium. Magnesium and iron, always present in the ash, do not influence the spectrum under these circumstances. See Pl. VI. Spectr. 8, marked "Ash."

Spectrum of sodium.

The spectrum of sodium (see Pl. V. Na) is distinguished by a yellow line, which coincides with the D line of Fraunhofer. On close inspection with the magnifying glass the line is seen to consist of two lines separated by a thin black line. When much sodium is in the flame a little yellow illumination appears on both sides of the line, as an indication of a continuous spectrum. This yellow becomes intense when metallic sodium in a burning state is analysed before the slit. Then the two yellow lines fuse together with the continuous dazzling yellow spectrum, and the dark line only is seen. It is not easy to determine whether the yellow lines actually become dark, as the light has a very dazzling effect upon the eye. This reaction of sodium is the most delicate as to sodium, and the most intense amongst the reactions of the metals of the alkalies and earths. When faint lines of other bodies fall close to these yellow lines the former become invisible, as the yellow ones dazzle the eye.

To make the feeble lines visible, it is frequently necessary to exclude



the sodium line from the field of sight by a special arrangement of screens, fixed as slides in the observing telescope. (Dr. A. Dupré.)

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

The eye can yet recognize one $\frac{1}{3000000}$th part of a milligramme of sodium by this reaction. As two-thirds of the earth are covered with a solution of chloride of sodium, and as great masses of seawater are constantly pulverised, the sodium is everywhere. Its antiseptic properties seem a special provision against the contamination of air, earth, and water.

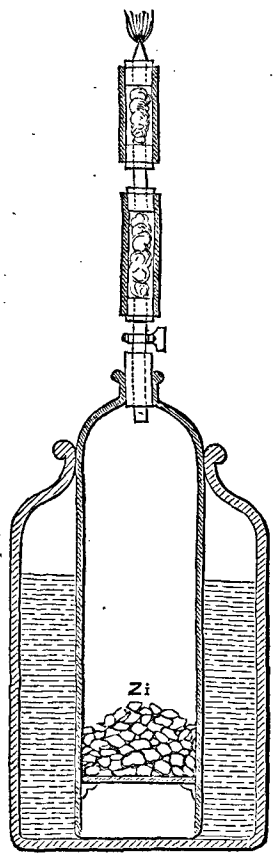
Spectrum of lithium. See Plate V. Spectrum Li.

Lithium yields as fervent vapour two lines—one Li α, red, strong; another Li β, yellow, feeble. Its reaction is very delicate, as $\frac{2}{1000000}$ths of a milligramme can yet be recognized. It is constantly present in sea water, salts, soils, animal and vegetable ashes, and is most extensively distributed over the earth. The ashes of human blood always contain a notable quantity of it.

Spectrum of potassium. See Plate V. Spectr. K.

Potassium gives a remarkable continued spectrum with two characteristic lines—one K α is red, in the ultra-red region, coinciding with the line A of the solar spectrum; another blue, K β, is in the violet end of the solar spectrum. These lines are comparatively feeble; to see them well in the magnifying spectroscope, great masses of material and great heat are necessary; it is best to use a flame of hydrogen, from a Döbereiner's apparatus.

Apparatus for hydrogen flame.



Improved Döbereiner's Apparatus for the Evolution of Hydrogen Gas.

The apparatus which I employ is made of stoneware; the inner jar fits tight into the neck of the outer, and stands upon its bottom. It carries the spelter upon a pierced movable tray. The outer jar contains the dilute sulphuric acid. As soon as the tap is opened, the acid enters the inner jar and evolves hydrogen gas; this rises, is filtered in the first cotton tube, again in the second tube containing fragments of pumice stone soaked with sulphuric acid, and is at last burned from a platinum jet, fixed in the proper place. The evolution jar must be kept sufficiently distant from all flames, so that when at the conclusion of an operation the collecting gas presses out the acid, and with it any surplus gas escapes, the mixture of air and hydrogen in the outer bottle may not be fired, but dissipated by diffusion. Orchard's compressed hydrogen can also be used.

Spectrum of caesium. See Plate V. Spectr. Cs.

The spectrum of caesium has thirteen lines, of which only three are characteristic, Cs α and Cs β are both blue, and situated midway between F and G, and Cs γ, situated between C and D. The other lines are yellow and green, and appear only when the light and heat of the burning metal are great and strong. There is always a blue continuous spectrum in the middle which makes particular screening, by means of the apparatus above described, necessary to see the lines one after the other. The three principal lines indicate yet $\frac{1}{20000}$ milligramme caesium.

Spectrum of rubidium. See Plate V.

Rubidium has 10 lines; of these, two red ones, Rb γ and Rb δ, are

situated on both sides of the line A, in the farthest part or end of the solar spectrum; Rb α and Rb β are violet, and situated between G and H. The other six yellow and green lines are not ordinarily visible because of the continuous spectrum which appears in the middle of the field. Of this substance $\frac{1}{5000}$ milligramme is yet necessary to exhibit the two violet lines.

Spectrum of calcium. See Plate V. Spectr. Ca.

Calcium gives a spectrum containing nine lines. Of these Ca α is rather a band of orange colour, situated on the red side of the D line Ca β is a broad green band between D and E. Between these two there are five lines which are of little use for the diagnosis of calcium, as the almost universal presence of sodium causes them to be so feeble as to become imperceptible. The eighth line is near Ca α, and towards the red end of the spectrum; the ninth line is violet, and seems to coincide with the two violet lines of rubidium, Rb α and Rb β. The reaction shows $\frac{6}{100000}$ milligrammes calcium chloride. It is of great use in animal and pathological chemistry. Having lately to examine a pathological biliary salt, I calcined a minute quantity, and analysed the hydrochloric acid solution of the ash. Ca α and β appeared, without any other metal, even sodium was absent. This information could not have been obtained except perhaps at the sacrifice of 50 times the quantity of material actually employed. Spectroscopy therefore effects an economy of valuable materials and products which exist in quantities absolutely limited.*

Spectrum of strontium. See Plate V. Spectr. Sr.

Strontium is distinguished from calcium and barium by possessing no green lines in its spectrum. It has eight lines, six red, one orange, and one blue, of which four are diagnostic. Sr α, orange, is situated near the sodium line towards red. Sr β and Sr γ are both red, and the fourth is the blue Sr δ, which appears between F and G, close to the two blue caesium lines. $\frac{6}{100000}$ milligr. strontium chloride give a clear reaction. Strontium has been used to investigate the possibility of the substitution of calcium by this earth in animal processes. Chicken were fed with food containing much strontia, and their egg-shells were examined. But it was found that nature could not be deceived into producing strontia shells instead of chalk shells. Only the smallest traces of strontia could be discovered in the solution of the egg-shells.

Spectrum of barium. See Plate V. Spectr. Ba.

Barium possesses the most complicated spectrum amongst alkaline earth metals. It has fifteen lines, of which two are red, one is orange, four are yellow, six green, and two greenish blue. Of these only three green lines are diagnostic. Ba α, a broad green band between E and b; Ba β, close to b, towards blue; and Ba γ, much less clear than the other two, situated between D and E, in the same place as Ca β. Between Ba α and Ba γ are three green lines, of which two have been marked Ba δ and Ba η; between b and F there are besides Ba β, two very feeble stripes of greenish blue; an orange-colored line, Ba ϵ is situated near to Sr α. Between the orange-colored and green Ba γ lines there are four yellow lines, very similar to the five yellow lines of the calcium spectrum. In the direction from the orange-red line towards the red end of the spectrum two red stripes are visible. $\frac{1}{1000}$ milligr. barium chlorate gives a good reaction. Increase of heat

* Spectroscopy is also useful in furnishing casual information. Thus the ashed end of a cigar, moistened with hydrochloric acid and held into the flame, yields the lines of sodium α, potassium α, lithium α, caesium α, rubidium α, and calcium α and β.

and quantity of material raises the brilliancy of all lines in proportion to their original intensity; but the feebly green Ꝑa η forms an exception, which, hardly visible in a feeble spectrum, which does yet show Ꝑa γ quite well, by intensity of heat and quantity of material becomes much more brilliant than Ꝑa γ. In cases of poisoning by barium salts (popularly known as muriate of barytes, or barium chloride), the spectroscope is able to furnish quick information.

Peculiar bearing of Ba η.

Of other metals occurring in the human body, magnesium, iron, and manganese give no spectra in their compounds which would be useful for the recognition of small quantities. Manganese, however, can be recognized as chloride (Plate VI. Mn Cl_6) by certain light lines, which seem to recur *as absorption bands in permanganates.* Of these we will speak lower down.

Spectrum of thallium. See Plate V. Spectr. Tl.

Amongst the poisonous metals there are only two, thallium and iridium, which can be recognized by the gas flame reaction. Thallium has but one line, Tl α, which is green, sharply marked, and situated between D and E close to the latter. It is very possible that thallium may contribute to the production of the insalubrious air which prevails in some sulphuric acid factories. To the animal body it is certainly a virulent poison, and the toxicologist has to be prepared for its diagnosis.

Spectrum of iridium.

Iridium imparts a violet colour to the flame. Its spectrum has two blue lines Ꝑr α and Ꝑr β, of which the former is near to Csα and towards the violet, the second about midway between Rb α and K β. The spectrum is most brilliant when the volatile chloride is used.

Spectra of other metals.

The spectra of the other metals occurring as poisons in the human body, and also those of iron, see Plate VI. Spectr. Fe, and cobalt, cannot be made to appear by means of so simple an apparatus as Bunsen's burner. They require either the heat of the electric spark produced by a strong battery and a Rühmkorff's induction coil, or the electrical arc between two carbon points of an electric lantern furnished with the power of at least 30 Grove's elements. Of these methods only the former offers opportunities for the recognition of small quantities of material; the latter requires larger quantities, and is therefore in its present shape not suitable for toxicological research. Of the heavy metals tin and mercury are best examined as gases, the former as chloride, the latter as metallic vapour. I will therefore describe their spectra with those of the permanent gases. Indium gives the spectrum pictured in In Pl. V. Plate VI. gives the spectra of didymium, erbium, copper, and silver, besides those of boracic acid, coal gas, and the electric spark.

Spectra of Simple, Permanent, and Compound Gases.

Spectra of gases.

Gases are examined by means of an electric induction spark which passes through their extremely attenuated atmosphere. The apparatus is termed after its inventor Geissler's tube, and consists of a ball and a cylinder of glass, united to each other by an extremely thin-bored thermometer tube. At each end of the tube electrodes of platinum or aluminium are inserted. The tube is filled with the gas, and then exhausted with the air pump until it has only the $\frac{1}{600}$ to $\frac{1}{700}$ part of the ordinary pressure of the air. In that state of attenuation the gas offers only a very slight resistance to the spark, which therefore passes through several feet lengths of tubing. The gas becomes very hot, and through this fervence emits brilliant and beautiful lights of various colours. The electrodes are ordinarily not volatilized, and not changed unless the gas combines with a portion of them.

Diagnosis of gases by their colour.

Name of gas.	Colour of the light. In the narrow part of the tube.	Colour of the light. In the wide part of the tube.
Hydrogen	Crimson	Reddish.
Nitrogen	Violet red	Violet red, feeble.
Chlorine	Green	Reddish violet.
Bromine	Greenish blue	Violet.
Iodine	Green	Fawn colour.
Tin-chloride	Golden yellow	Deep blue.
Silicium-chloride	Whitish	Fawn colour.
Carbonic acid	Greenish white	Greenish white.
Hydrocarbon, $\mathfrak{C}\,H_2$	Rose coloured	Greenish.
Hydrocarbon $\mathfrak{C}\,H_4$	Brilliant white	—
Acetylene $\mathfrak{C}_2\,H_2$	Brilliant white	Brilliant white.

Diagnosis of Gases by their Spectra in the incandescent State.

Diagnoses of gases by their spectra.

Oxygen can only be examined with electrodes of aluminium; platinum ones are oxydised. The spectrum, obtained by placing the Geissler's tube through which the electric spark is passing before the slit of the spectroscope, shows nine coloured lines. The most brilliant are a red and a violet one, then follow in order of strength of light two green, two blue, two greenish yellow ones, and lastly a dark red line. None coincide with any of Fraunhofer's lines.

Oxygen.

Hydrogen forms three light lines. The red line near C is the most intense; next is a greenish blue line in the place of F, and the third violet line is feeblest. Water vapour decomposes any electrodes, and gives the hydrogen spectrum.

Hydrogen.

Carbonic oxyde is obtained by the examination of carbonic acid, which is reduced. Its spectrum contains eight coloured lines, between which 10 dark lines are distributed. The most prominent are, one green, one greenish yellow, and two violet ones.

Carbonic oxyde.

Many hydrocarbons yield identical spectra when burned in the air. The inner cone of ordinary coal gas burned in Bunsen's burner, particularly the variety provided with a blowpipe tube, gives a spectrum which varies slightly with the quality of the gas. Four conical* bands are easily distinguished, of which two green ones occupy the place of $\mathfrak{B}a\ \beta$ and $\mathfrak{B}a\ \gamma$, the space between being illuminated by feeble green; then there is a blue band in blue, and a violet one in the violet region of the colour spectrum. There is a generic similarity of this spectrum with that of boracic acid in the gas-flame (four green bands), which inclines one to the idea that it might be due to carbon as the latter is to boron.

Hydrocarbons.

Anhydrous acetic acid, alcohol, and ether yield, the former nine, the latter two eight lines, which belong to carbonic acid (resp. oxyde) and hydrogen.

Acetic acid, Alcohol and ether.

* Conical, showing that the phenomenon is limited to a space hardly longer than the slit of the spectroscope, and more intense at its base than at its summit.

Chlorine.

Chlorine yields six coloured and eleven dark lines. Diagnostic is a band of four yellowish green lines, a broad green line, and a treble blue line. The distribution of the coloured bands amongst the dark ones is very intricate.

Chloride of tin.

In chloride of tin three diagnostic chlorine lines appear, but five other lines, one yellow, another yellow double line or band cut in two by a lighter line, a green and a blue line, necessarily belong either to the tin or to the subchloride of tin, either of which may be formed in the reaction.

Hydrochloric acid.

Hydrochloric acid shows the lines which are peculiar to hydrogen and chlorine.

Chloride of silicium.

Chloride of silicium shows twelve lines, three of hydrogen (impurity), three of chlorine; five or six lines only are therefore diagnostic of silicium, or silicium chloride; of these one is red, one orange, two are dark violet, and one a light green band with a lighter green line in the middle.

Chloride of phosphorus.

Burning phosphorus gives a continuous spectrum; its dilute vapours in a tube do not permit the spark to pass. Its chloride yields black and red stripes, three lines diagnostic of chlorine, and three lines, one orange, one orange yellow, and one violet, which are very brilliant and intensely coloured, and belong either to phosphorus or its chloride.

Bromine spectrum.

Bromine yields a spectrum with nineteen light lines, of the most varied colours, two red, one orange, eight green, four blue, and four violet. A green and a blue line are the most brilliant.

Iodine spectrum.

The spectrum of iodine contains more than twenty lines, of which four red, one orange, four yellowish green, two green, two blue, and two violet, are particularly clear.

Mercury.

Mercury in a tube so attenuated that it boils at from 40° C. to 50° C. shows nine lines, one yellow, one green, and one violet, one being distinguished by brilliancy.

Nitrogen.

The spectrum of nitrogen is very complicated, and extends from the line B to H; in the part from the red to light yellow it contains seventeen dark lines at perfectly equal distances from each other; in green there are further seven dark lines, at unequal distances from each other. At F the spectrum begins to show coloured lines and groups of lines on a dark field. Of these thirteen can be distinguished, amongst which a blue one and several violet lines are the most brilliant. The violet end of the spectrum extends very far, and can be made beautifully visible by fluorescent substances. These substances show that hydrogen possesses no such fluorescent spectrum. When the slit of the spectroscope is made wider, the groups of lines of the nitrogen spectrum fuse to continuous bands of greater width without any dark intervals. This illustrates a frequent occurrence, namely, that broad bands, by narrowing of the slit, are resolved into bands of the width of the slit. The spectrum of air contains the lines of nitrogen and oxygen.

Practical application of the above spectra.

It must be left to the future to decide how far these spectra can be practically utilized in the diagnosis of gases which occur in the animal economy. Such gases as occur in morbid emphysemata (in the cellular tissue of cows during cattle plague, in contused limbs with effused blood) in the blood in various conditions, in certain internal cavities or tissues as results of diseases, have hitherto mostly escaped analysis, as their small quantity makes the ordinary methods inapplicable. The attention of inquirers must henceforth be directed upon their analysis by means of the electro-spectroscopical method.

Application of the Spectroscope to the Diagnosis of Coloured Gases, Fluids, and Solids, by means of the Phenomena of Absorption.

When coloured translucent bodies are placed in the path of the ray of sun or lamp light before it enters the prism, they frequently effect a change in the appearance of the spectrum. Certain parts are extinguished, others altered in colour, and these effects are found to be specific to bodies of definite chemical composition. The gases of iodine, bromine, and nitrous acid exhibit a great number of hair-fine lines, similar to the lines shown by the solar spectrum itself, but of different theoretical value. The lines of nitrous acid increase in number by heat, and decrease by cooling. The vapour of indigo on the other hand possesses no lines, all the more singular as its solution has a particular line or band in its spectrum. Such changes in the spectrum indicate that these bodies so alter the motion of a certain part of the light that it is unable to produce an effect upon the retina of the eye; the change is termed absorption. Amongst the solid bodies the coloured glasses are the most powerful in the production of these phenomena. The red varieties, termed ruby-glasses, which owe their tint to suboxyde of copper, are the most homogeneous. They only allow red and a small part of orange to appear in the spectrum; all other colours are more or less absorbed. The orange-coloured glasses containing iron oxyde, the light yellow ones containing silver chloride, the smoke-yellow ones containing antimoniate of potassium or soot, and the green glasses containing oxyde of copper or chromium, allow the greater part of the spectrum to F and G to pass. But most blue glasses show particular obscuration in the shape of bands. As these are frequently used as spectacles and windows in eye-infirmaries, and are known to be coloured by cobalt, it is necessary to consider the influence of this metal. Some sodium diborate moistened with a solution of cobalt-chloride was fused to an eye of platinum wire, and the pellucid blue pearl while soft pressed between platinum plates; it showed three bands in the spectrum.

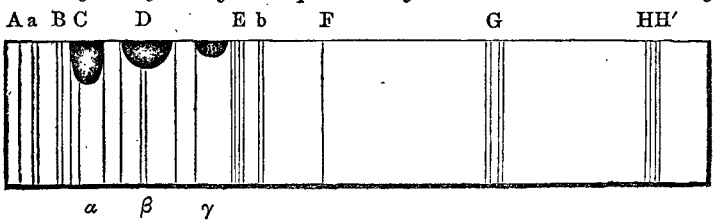
Definition of absorption.

Coloured glasses.

Cobalt-glass.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 25′ — 142° 6′	= 0° 19′	3	α
2 in yellow to green	= 141° 55′ — 141° 24′	= 0° 31′	2	β
3 in green not clear.	= 141° 12′ — 140° 53′ (approximatively).	= 0° 19′	1	γ

Intensity Diagram of the Spectrum of Sodium Diborate Cobalt-glass.



No further shades in green and blue.

The spectrum of a beautiful blue glass (I.) from Messrs. Powell & Son's factory in Whitefriars gave

Blue glass No. 1.

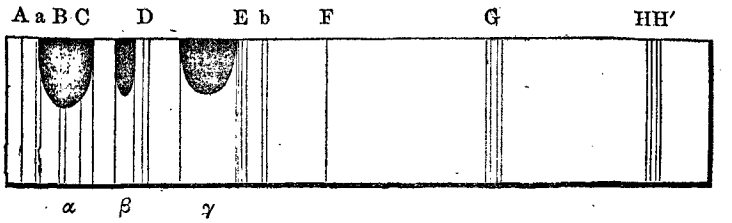
Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 43′ — 142° 12′	= 0° 30′	5	α
2 red and orange	= 142° 0′ — 141° 48′	= 0° 12	4	β
3 in green	= 141° 24′ — 140° 51′	= 0° 33′	4	γ

No shades in green and blue.

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

Intensity Diagram of Spectrum of Blue Glass. No. I.



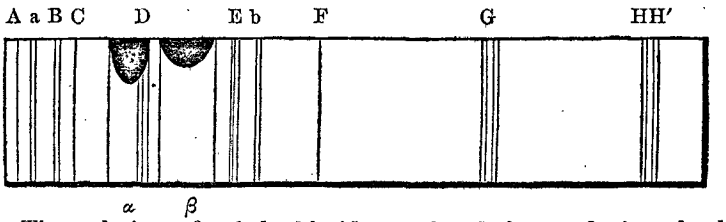
Blue glass. No. II.

Specimen of blue glass No. II.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 0′ — 141° 36′	= 0° 24	3	α
2 in green	= 141° 30′ — 141° 0′	= 0° 30	2	β

No further shades in green and blue.

Intensity Diagram of Spectrum of Blue Glass. No. II.



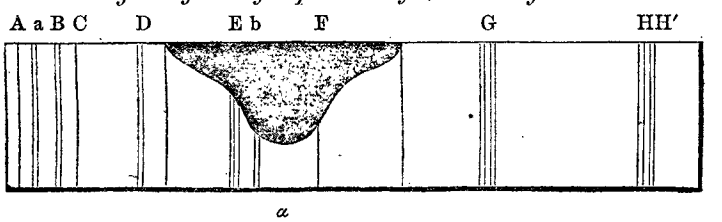
Solution of cobalt chloride.

The solution of cobalt-chloride employed for producing the blue bead above described had a pink colour, no absorption in red, yellow less vivid, and a broad band beginning with green and reaching to blue.

$$\alpha = 141° 30' - 139° 12' = 2° 18'.$$

The blue was then continued to the end.

Intensity Diagram of Spectrum of Solution of Cobalt Chloride.



This red solution, therefore, absorbs the green rays as completely as the blue glass absorbs the green of plants.

The foregoing observations can be multiplied and varied upon different kinds of glass, several layers of progressive thickness, and thereby undergo great variation. All effects, however, result in a great abbreviation of the red part of the spectrum, in a pallor or absorption of the yellow, in an obstruction and absorption of the green, and perhaps a prolongation of the blue. Such glass therefore excludes from the eye a great mass of colours, or of such light as has the most exciting effect upon the retina.

Manganese glass.

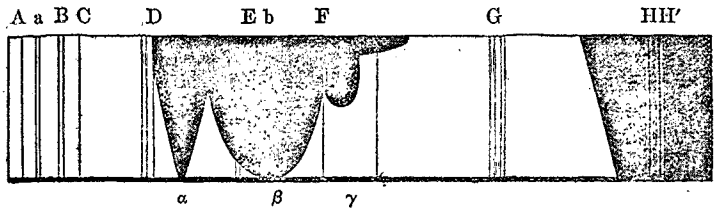
Solution of permanganate.

Some violet glasses, coloured with oxyde of manganese, show a darkness about D, and another in dark green and beginning of blue. We observe phenomena reminding of these in solution of permanganate of potassium. A very dilute solution is dark rose-pink, and shows an absorption band from yellow to blue, and some further shading.

Measurement.	Width.
141° 36′ — 140°	= 1° 36′ for black band.
140° — 139° 30′	= 0° 30′ for shading.

The first part of band seems to be a narrow band, α, a small interval of feeblest light succeeding ; then a broad band, β, then a narrow feebler band, γ, seems to follow ; ultimately the shading nearest to blue.

Intensity Diagram of Potassium Permanganate Spectrum.



The violet is absent. Compare with these absorptions the four positive bands of manganic chloride.

Didymium crystals.

Of crystals, those of didymium salts offer the most interesting phenomena of absorption (see diagram in Cholera Report, p. 493), as they are the direct reversion of the spectrum of the fervent didymium flame.

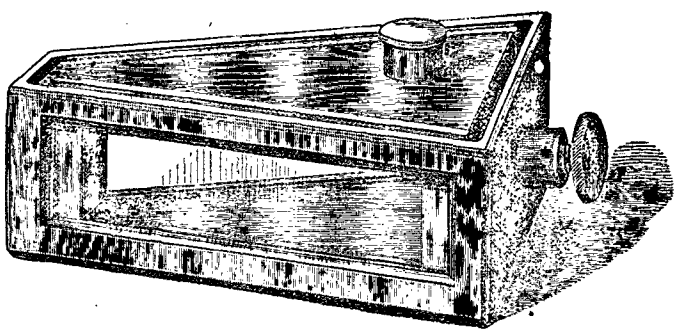
Erbium.

Erbium offers similar appearances, through the reverse of its absorption spectrum is not produced by its vapour, but appears by the simple glowing of a bead of its earth.

The Effects of Fluids upon the Spectrum.

Effects of fluids upon the spectrum.

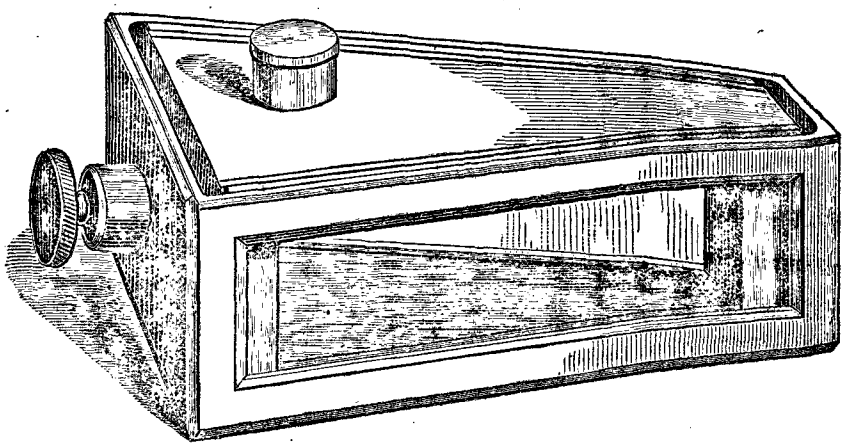
These are absorption and fluorescence phenomena. As they may be useful hereafter for the ready diagnosis of poisons and medicines, and for other purposes of forensic medicine, I have subjected many of them to examination. The principal application of spectrology will, however, be to the chemistry of the normal and pathological ingredients of the body. While, therefore, I shall state of general researches only the shortest results, I shall devote a special chapter to the elucidation of the spectral phenomena of the blood, its physiological and pathological changes, particularly those effected by poisonous gases and fluids, and to the changes effected in the spectral phenomena of blood by chemical agents, or the spectrology of hematine and many of its derivates. The latter will afford me an opportunity for proposing a new method for the discovery of blood in medico-legal cases under particularly difficult circumstances, where hitherto all other proceedings have failed.



Hollow Prism of Gutta Percha, glass and brass.

Many of these solutions were examined in test tubes, or bottles of larger diameter. Others were placed into hollow prisms which I had made for the

purpose. Such a prism consists of a wedge-shaped cell of gutta percha, open on both its long sides and lined with india rubber; two pieces of plate-glass are strongly pressed upon these sides by means of the brass frame and screw at the end. When closed the apparatus can be filled and emptied by the aperture on the top, shown in the engraving as closed by the gutta percha stopper. It is never taken to pieces except for thorough cleaning. In such a prism one and the same fluid can thus



Larger hollow Prism for more dilute Fluids.

be examined in layers varying from half a centimetre to three centimetres in thickness. Two prisms can be used placed in opposite directions for studying the complementary effects of different solutions, *e.g.*, of sulphocyanide of iron and prussian blue in oxalic acid. Among the apparently monochromatic fluids the yellow-coloured ones mostly allow the entire spectrum to pass. The pure yellow tinctures of sabadilla, datura, belladonna root, colchicum, colocynth, nux vomica, and cantharides offer no particular features in the spectrum. Those which like certain kinds of olive oil show absorption, owe this quality to an admixture of impurity. Of red and blue solutions, those of sulphocyanide of iron, of prussian blue, and of the ammoniacal solution of copper-oxyde, permit a considerable part of the spectrum to pass. Sulphocyanide, however, when coupled with a layer of prussian blue, extinguishes the entire spectrum.

Prolongation of red part of spectrum.

Bands from impurity.

Some solutions prolong the red part of the spectrum in the direction of the heat spectrum. This peculiarity belongs to a particular variety of pure yellow olive oil, and to the essential oil of the Bergamo lemon peel; also to certain kinds, not all varieties, of tincture of rhubarb, after dilution with spirit of wine. These fluids also exhibit a black absorption band in red; in the less pure and very impure olive oil two more feeble absorption bands in green appear. All these absorptions are probably due to the admixture of xanthophylline. Animal fats, including human, have never yet been found to possess absorptive qualities, although they are frequently very powerfully fluorescent. It is curious that some, not all varieties of the tincture of rhubarb, orange peel, and of compounds made with their aid, show bands in red of variable breadth, which have some similarity to the band produced by hematine in alkaline alcoholic solution, and to the first band in red of acid hematine solutions; but the differences are clearly and easily evolved by careful manipulation, to be described below.

Of poisonous tinctures, that of aconite yields a spectrum coinciding by its bands with that of xanthophylline produced from chlorophyll. (Valentin; Simmler.) The tinctures of hemlock and foxglove yield two xanthophylline bands, of which the second is rather a narrow line than a band. The tincture of hyoscyamus shows only a band in red, and the rest of the spectrum clear.

Tincture of aconite and other vegetable poisons.

Many alkaloids yield peculiar colour-tests with various agents, such as sulphuric acid and potassium diochromate, manganese, nitric acid, and others. Not one of these, whether possessing poisonous, medical, or indifferent properties, yields by such reaction coloured fluids which show any particular spectral phenomena or absorption bands. (Valentin.)

Colour-tests of alkaloids yield no bands.

Many coloured fluids of organic and inorganic origin show one or more narrow or broad bands in the yellow, green, or blue part of the spectrum. Such are chloride of chromium, the solution of cobalt, permanganate, indigo, and others. Of all these I shall attempt a systematic arrangement in a future elaboration.

Various fluids give bands in yellow to blue.

Solutions which absorb red end.

Some solutions which have little colour of themselves, such as iron chloride and copper nitrate, sulphate, and acetate, absorb (like the oxalic acid solution of prussian blue already mentioned) the red part of the spectrum. These latter blue solutions are therefore frequently used in investigations concerning the fluorescence of substances.

Peculiar effect of potassic solution of chromic oxyde.

The potassic solution of oxalate of chromium-oxyde, even in so dilute a state that the eye hardly perceives any coloration, absorbs the yellow rays in the neighbourhood of D. Thicker layers or more concentrated solutions absorb the rest of the yellow, the orange and the green rays next to yellow. Very concentrated solutions allow the red rays only to pass, and then a dark line of Fraunhofer's can be seen, which is ordinarily visible with the best prisms only. (Brewster.) Oxalic acid mixed with red chromate of potassium gives a dark violet fluid, which allows red to pass, absorbs all light from C to half-way between C and F, and then green to a little beyond F. The dry residue of this fluid, which forms into scales, gives a similar spectrum. (Valentin.) I have examined the green fluids which chromate and sulphuric acid give with matters which are oxydized with the mixture, *e.g.*, alcohol, and found them to yield particular absorptions. The permanganate spectrum has already been mentioned, as also the phenomena exhibited by didymium compounds. Those of uranium also show absorption bands. (Brewster and Gladstone.)

Green solutions of chromate, sulphuric acid, and alcohol.

Dyes.

Amongst the coloured substances occurring in nature, or produced by art, which are used for dyeing, none appear to possess the properties of simple colours, inasmuch as all permit more or less of different colours to pass. If any possessed only one colour, it would allow only that colour to pass, and would give a spectrum showing complete darkness everywhere except in one particular place, where a coloured band of the width of the slit of the spectroscope would appear. Nevertheless many of these matters have peculiar effects upon the spectrum, by which they can be distinguished, however similar they may appear to each other in ordinary daylight. Some of the solutions, when examined in certain concentrations, allow no light at all to pass; others allow red to pass even through very thick layers; others, like picric acid, allow red, orange, yellow, and green to pass. Their phenomena on progressing dilution are also noteworthy. Frequently the blue and violet part become visible first, and the absorption remains only in the yellow and green part. Picric acid, however, absorbs the violet in even very dilute solutions, and prussian blue in oxalic acid the red. Most substances have a limit of dilution, which, when transgressed, produces a complete disappearance of all absorptions. This limit can only be ascertained if

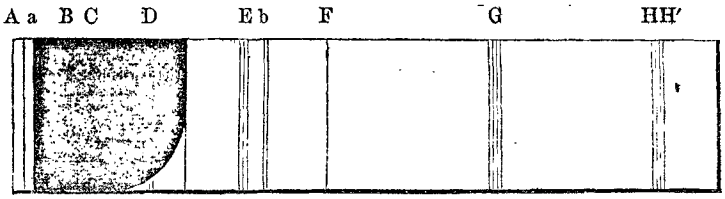
Limits of dilution.

Aniline dyes.

strength of solution and thickness of layer interposed are carefully noted. Some bodies bear from five to ten-fold the dilution of others before their absorptions disappear. This relative power of absorption, as governed by quantity, temperature, solvent, should always be borne in mind in any development which it may be intended to give to the spectral method. In the following description reference is mostly to solutions of medium concentration, which allow the absorption bands, or other principal phenomena, to appear best.

Aniline Dyes.—The concentrated solution of roseine allows red from A to C to pass, and absorbs the rest of the spectrum. A solution of 1 in 10,000 shows an absorption reaching from D to half-way between F and G. On progressive dilution the band becomes narrower, until in a solution of 1 in 100,000 it assumes its narrowest limits; these it retains until it disappears at a dilution of 1 in 600,000.

Diagram of Spectrum of Aniline Ponceau (green) in alcohol.



Aniline Blue.—The concentrated solution allows red to pass; 1 in 5,000 shows a broad band between C and E, which on dilution becomes narrower, and remains with the D line for its middle. At 1 in 8,000 it reaches its narrowest limits, and on progressive dilution it becomes gradually feebler and disappears at 1 in 20,000.

Nicholson blue has the same spectra as magenta, to be described immediately.

Aniline Violet is very similar to the foregoing spectra, but its absorption band is situated intermediately between those of the other two. It disappears on dilution to 1 in 60,000. A mixture of roseine and aniline blue shows a similar bearing.

Diagram of Spectrum of Aniline Violet, or "Magenta."

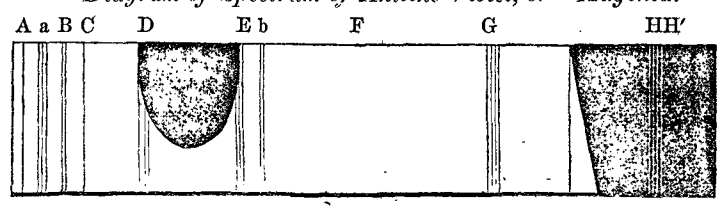


Diagram of Spectrum of Concentrated Solution of Humbold's Violet in Water.

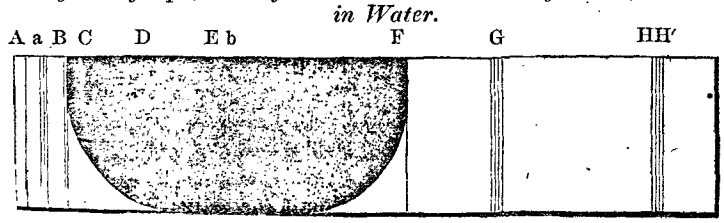
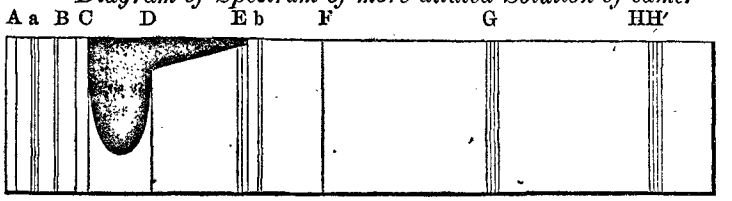


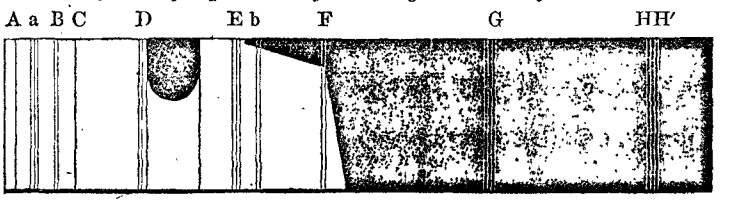
Diagram of Spectrum of more diluted Solution of same.



Logwood.—A decoction of logwood, when sufficiently concentrated, allows red light only to pass. Diluted with from 7 to 8 parts of water blue from F to G appears. Diluted with from 18 to 20 parts of water, the absorption band is at its minimum width; it disappears when the original decoction is diluted with 24 parts of water. Logwood.

Brazil-wood.—A decoction of this wood allows red and orange to pass; 16 times diluted blue and violet appear; a band remains between D and E, and disappears on dilution of the original solution with 45 times its bulk of water. Brazil-wood.

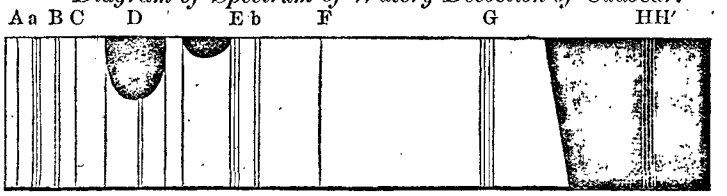
Diagram of Spectrum of Watery Solution of Brazil Wood.



Santal-wood.—The alcoholic extract of this wood passes first red, then orange rays; diluted 35 times yellow and green to E appears; blue is seen when the dilution is 55, and a band appears from E to beyond F. At 60 dilution this band separates into two narrow ones, of which one situated between E and C disappears only at a dilution of 200, while the other, situated near F on the side towards G, becomes invisible somewhat earlier. Santal-wood.

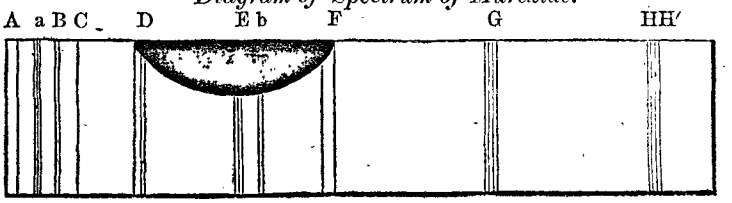
Cudbear shows red and yellow, and then retains two absorption bands on the violet side of D, which remain to the 23rd dilution. Cudbear.

Diagram of Spectrum of Watery Decoction of Cudbear.



Murexide, produced from uric acid by nitric acid and ammonia, is similar to some violet aniline dyes, but is distinguished by its spectrum, which is as follows: Murexide.

Diagram of Spectrum of Murexide.



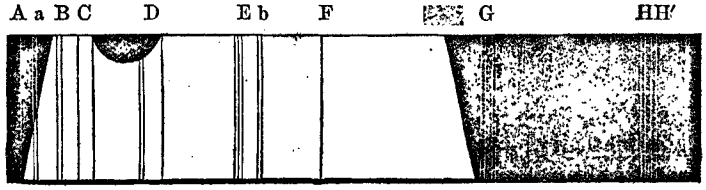
APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

Litmus.

The blue tincture of *Litmus*, obtained by digesting the little magnesite cakes, exhibits a band in yellow 142° 12′ — 141° 30′ = 0° 42′. Spectrum cut off at 138° 48′; red slightly shortened.

Intensity Diagram of Litmus Spectrum.



Reddened by hydrochloric acid the tincture shows no band; the blue becomes feeble; all is turbid; again made blue by caustic potash the former band reappears, and the rest of the spectrum becomes again very bright.

Indigo.

The similar spectrum of indigo and its sulpho-compounds I have described in the cholera report.

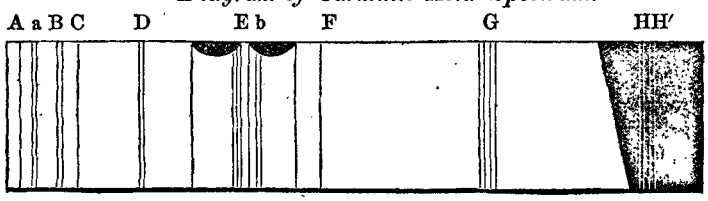
Cochineal alizarine.

Cochineal, the crimson matter from the cochineal insect, and alizarine, a colouring matter extracted from madder, are similar to santal-wood in this that they show two bands each. The powdered cochineal boiled in water on appropriate dilution shows two bands,

	Measurement.	Width.
1 in green	= 141° 12′ — 140° 48′	= 0° 24′
2 in green to blue	= 140° 42′ — 140° 12′	= 0° 30′.

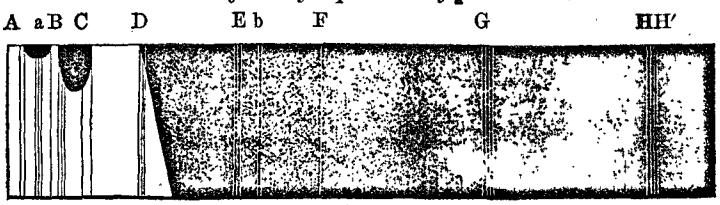
Blue continued to the end. Intensity of both bands when first seen separate = 1.

Diagram of Carminic Acid Spectrum.



Some kinds of cochineal yield so-called neutral solutions, the spectrum of which shows only one band at any degree of dilution to disappearance. By alkali the absorptive power of carminic acid is much increased, and the two bands appear, even in dilutions containing much less of the acid. Ammoniacal solutions are quickly oxydised and lose their absorption bands. The bands of alizarine are situated more towards the blue than those of carminic acid.

Diagram of Spectrum of Alizarine.

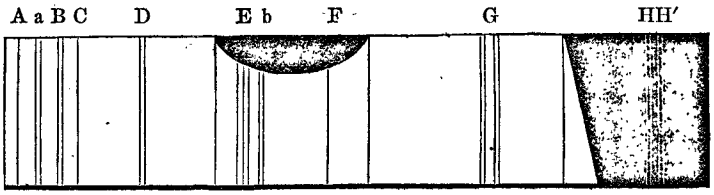


On comparing the red-coloring matter of some other lower animals, I found that the red fluid (blood) of the common earthworm contains

hematocrystalline, the same as is contained in the blood corpuscles of the vertebrata. It is, however, not attached to corpuscles in the earthworm, but dissolved.

Blood of earthworm contains hematocrystalline.

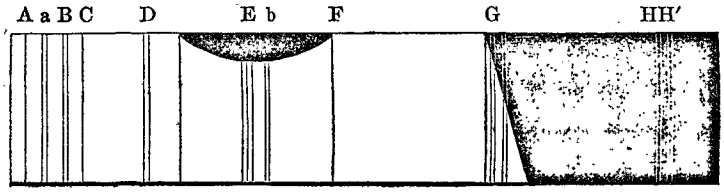
Diagram of Spectrum of Extract of Chromatophores of Lobster.



The chromatophores of the lobster contain a red matter of the colour of blood. On microscopic examination this is seen to be contained in spiderlike cells. It is insoluble in water, a little soluble in alcohol, more soluble in acetic acid and alcohol. The solution is yellowish red. Spectrum: red and yellow, complete; in green at 141° a shading begins, which passes into a kind of violet (not black), and ends with the beginning of blue at 139° 30′ width of band = 1° 30′. The end of the violet is at 137° 36′. A layer of fluid of double the thickness cut off the spectrum at 141° 18′. (See Plate III. fig. 6.)

Chromatophores of lobster.

Diagram of Spectrum of Red Currant Juice.



Red currant juice mixed with three times its bulk of water gave a red fluid, the spectrum of which showed apparent similarity to that of the lobster chromatophores. Red, yellow, then dark at 141° 24′ to 140° 12′ = 1° 12′. Blue to the end. (See Plate III. fig. 7.)

Red currant juice.

Apart from the chemical differences of these solutions, the spectral ones are eminently diagnostic. Passing over the width of the bands we perceive in the nature of the obscuration a difference, the band in the currant juice is simply dark, that in the chromatophores solution has a fluorescent tinge.

Of yellow dyes picric acid is a good type. The saturated alcoholic solution in a layer of one centimetre in thickness allows red, yellow, and green to near F to pass; diluted with two alcohol it extends to F; on gradual dilution the spectrum extend slowly until at dilution 150 blue to G appears, at dilution 400 G is cleared, and at 700 the colour extends to near H. The entire spectrum is only lighted up at dilution 2,500.

Yellow dyes. Picric acid.

The tincture of turmeric, when saturated, has a reddish yellow colour. In layers of one centimetre thick it allows colours from red to half green 140° 48′ to pass. It shows a beautiful green fluorescence in the cone of sunlight condensed by a system of quartz lenses.

Turmeric.

Many yellow dyes show similar phenomena, amongst them camboge, yellow wood, French berries, purrée, annotto, sumach, and bark or quercitron.

The knowledge concerning these bodies can only attain its full development by studies upon pure immediate chemical principles, instituted with the most expansive spectrometric methods, and absolute regard to the phenomena of fluorescence.

Various yellow dyes.

In these respects the vegetable world seems to offer an almost endless field of study. Its phenomena here and there obtruded themselves upon

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

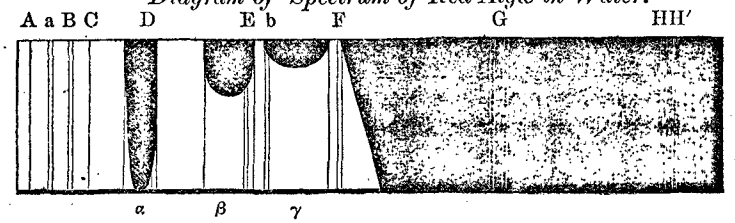
Red algæ on human bone.

my attention without my seeking. Thus a human thigh bone which was macerating in the conservators apartment of St. Thomas's Hospital was brought to me for examination. It was covered with a red gelatinous mass. The glass vessel in which it was steeped in water was similarly covered. The microscope showed the red material to consist of minute cells in a gelatinous mass, with which green larger cells were interspersed. The water filtered from them contained a number of these minute bodies in suspension; it was red, and gave the following spectrum:—

Band.	Measurements.	Widths.	Intensity.	Rank.
1.	142° 0′ — 141° 36′	= 0°24′	7	α
2.	141° 12′ — 140° 46′	= 0°26′	2	β
3.	140° 39′ — 170° 0′	= 0°39′	1	γ

Spectrum cut off at 139° 54′.

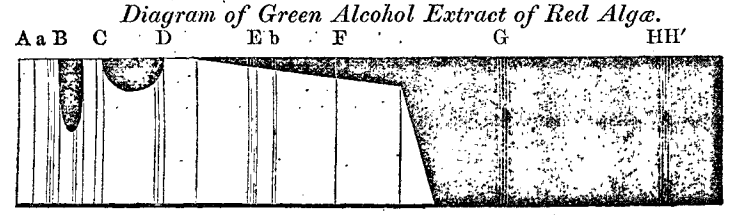
Diagram of Spectrum of Red Algæ in Water.



This spectrum presents a matter in its natural state. The following spectrum will exhibit the difference which was effected in its nature by alcohol and boiling. The mass appeared fluid while boiling, but on the filter it completely gelatinised, and the fluid ceased to percolate. The filtrate, which was green, remained fluid. (See also Plate III. fig. 8.)

1 in red	142° 37′ — 142° 25′	= 0° 12′	5	α
2 in or to green	142° 12′ — 141° 36′	= 0° 36′	1	β
3 in green, shaded at 141° 18′ limits uncertain			1	γ

Diagram of Green Alcohol Extract of Red Algæ.



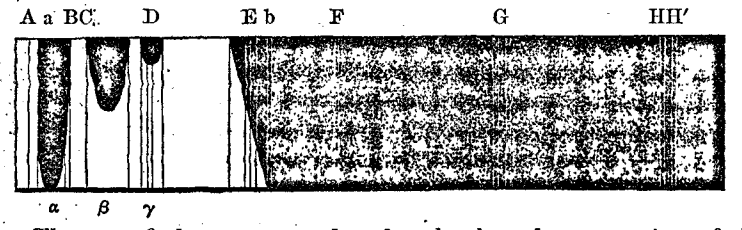
Green algæ in pond at St. Thomas's Hospital.

Green Matter from Cellular Algæ in the Pond of St. Thomas's Hospital Gardens.—These matters are of some interest, as their origin (summer 1866) was by uninformed persons ascribed to the proximity and operations of the Pathological Laboratory, which is situated upon the bank of the pond. The algæ were minute single cells with granular contents, many of the corpuscles being green. Filtered from the water and dried, a light green mass appeared, firmly adhering to the paper. This adhesion was owing to the gelatinous colourless material in which the cells were imbedded. The paper yielded nearly all its green colouring matter up to alcohol. The solution was green, fluoresced red in sunlight, and gave a blood-red cone with a lens. It had, therefore, the essential properties of chlorophyll; of its spectrum the red was shaded.

1 in red	142° 48′ — 142° 30′	= 0° 18′	10	α
2 red to yellow	142° 18′ — 142°	= 0° 18′	5	β
3 or to green	141° 54′ — 141° 36′	= 0° 18′	2	γ

Green shading quickly at 141° 12′, cut off at 141°. (See Plate III. fig. 9.)

Diagram of Spectrum of Green Cellular Algæ.



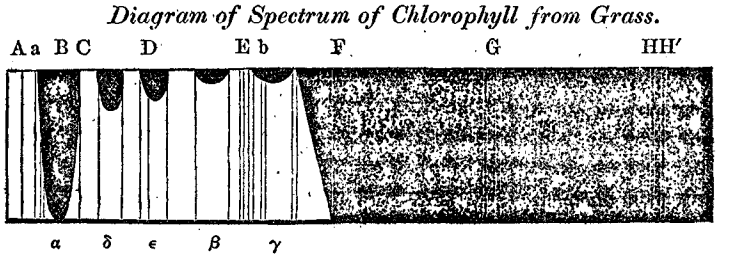
The rest of the spectrum though colourless shows a curious feeble illumination. Having disposed of this objection to the Pathological Laboratory, I compared the chlorophyll from grass. This was all the more interesting as Berzelius had mentioned his belief that chlorophyll and the green colouring matter of bile, biliverdine, were identical. Grass was extracted with caustic potash, and the solution precipitated by hydrochloric acid. The green precipitate was extracted by alcohol. It had stood more than a year when spectroscopically examined.

Chlorophyll from grass.

Bands.	Measurements.	Width.	Intensity.	Rank.
1 in red	142° 48′ — 142° 18′ =	0° 30′	10	α
2 red to orange	142° 12′ — 141° 54′ =	0° 18′	2	δ
3 orange to green	141° 42′ — 141° 24′ =	0° 18′	1	ε
4 in green	141° 12′ — 140° 54′ =	0° 18′	8	β
5 in green to blue	140° 42′ — 140° 18′ =	0 24′	5	γ

Last term difficult to read. Blue cut off; feeble illumination of colourless end. The solution fluoresces red in solarlight pencil. (See Plate III. fig. 10.)

Diagram of Spectrum of Chlorophyll from Grass.



This substance is therefore quite different from the one extracted from the algæ, and corresponds to the description first given of the green colouring matter of plants by Sir D. Brewster. Several chemists deny that this spectrum belongs to a simple body, and the comparison of the spectrum of the green algæ seems to confirm that opinion. For its three bands are so similar to the first three bands of the extract from grass, that they may well be considered to be identical. One of the bands certainly exists in the green leaves of some plants, but the presence of all has not yet been proved. Sunlight or electric or Drummond's light must be employed for their investigation. The five-band spectrum is interesting on account of a certain similarity to the spectrum of some forms of cruentine, of which more below. Some colouring matters derived from bile, to be described below, yield spectra, which have bands not dissimilar to the three-band chlorophyll from algæ. But true biliverdine in alcohol shows no bands; one half of its spectrum is of a brilliant red, without any yellow, the other half is of a splendid green. In sunlight it shows no fluorescence.

2.—*Spectral Phenomena of the Blood, its Physiological, and Pathological Changes, particularly those effected by poisonous Gases and Fluids; its Changes by chemical Agents.*

The spectral phenomena of the blood are a combination of optical effects produced partly by chemical, partly by mechanical agencies. The mechanical ingredients act rather as impediments to clear perception or complete perception of all appearances, and have therefore to be eliminated. But even after that the chemical ingredients remain in so complex a mixture as to be liable to change, and to exhibit imperfect spectra. Perfect spectra can only be obtained upon chemically pure matters, and when these are once established as standards, the more obscure and imperfect spectra can be referred to, compared, or identified with them. I shall show further on that acid hematine, when prepared pure, shows four or five absorption bands, while only three are seen upon less pure solutions, and only one when these less pure solutions are not viewed in sunlight or oxy-hydrogen light, but in the ordinary gas-light or lamp-light of laboratories. For these and other reasons I prepared a number of specimens of hematocrystalline and hematine, and their derivates, in various ways, and subjected the products to spectropopy.

Beating the blood.

Mode of separating Blood-corpuscles from Fibrine and Serum.—As the corpuscles become entangled in the coagulating fibrine, the blood has to be beaten or stirred with a broom of decorticated birch or whalebone. The mixture of serum with red and white blood-corpuscles can, in the present state of science, not be separated into its constituents so as to leave the corpuscles pure and unchanged. Chemical means have therefore to be employed, by which this separation may be effected with a minimum of change.

Separating the blood-corpuscles.

Solution of salts.

There are solutions of salts of a certain degree of concentration. Sulphates, carbonates, and chlorides of sodium or potassium have been employed. The concentration of these solutions should not be greater than is required to effect the object. Of chloride of sodium the smallest quantity seems necessary, of carbonate of potassium the largest.

NaCl solution.

One volume of saturated chloride of sodium solution may be mixed with from 9 to 19 volumes of distilled water. To such a solution one volume of blood, beaten and filtered through calico or linen, is added, and stirred. The mixture is allowed to stand at a very low temperature, in ice and water, to prevent decomposition. When the corpuscles are deposited the supernatant liquid is decanted, and the sediment is again stirred with the same quantity of the chloride of sodium solution as before. This is repeated a third and fourth time.

Decanting and filtering.

The decanted liquid is by no means clear, but contains many blood corpuscles in suspension. It is very difficult to filter it, but I have to some extent succeeded in filtering it through calico extended almost horizontally over a frame. It is necessary to filter in warmer weather because the mixture cannot be left at rest for longer than three days, even in cold weather, and during that time only few descriptions of blood deposit the greater part of their corpuscles. Every three days the salt water has therefore to be renewed, and the completion of this washing process therefore takes from nine to twelve days.

Washing.

Varying time required by the corpuscles of different animals to deposit.

The blood corpuscles obtainable from the slaughter-house, from oxen, sheep, and hogs, are very imperfectly deposited, and with them washing can hardly be effected more than three times. The blood corpuscles of men, dogs, cats, guinea-pigs, and rats are deposited much sooner. Those from birds and amphibia settle the quickest.

Peculiarity of horse blood.

The blood corpuscles of the horse show a peculiarity in this, that they

sink quickly in their own serum, and can therefore be separated from it a first time without addition of salt water. But they deposit very slowly in salt water, and therefore offer no advantage over oxen and sheep's blood.

Mode of extracting and purifying hematocrystalline.

Mode of extracting Hematocrystalline.—When the blood corpuscles thus freed from serum are shaken with ether and water, the red-coloured ingredient dissolves in the water; and if this solution, after rapid filtration, be exposed to a low temperature, crystallises at once, if it came from dogs, rats, guinea-pigs, or squirrels; but if it came from birds crystallises only after addition of one quarter of its volume of alcohol of 80 °/₀, and exposure to a cold of from — 5° to 10° C. The crystals obtained are separated by filtration, washed with dilute alcohol (1 part of 80 °/₀ in 4 water), pressed between blotting paper, redissolved in a minimum of water, filtered again, mixed with $\frac{1}{4}$ volume of alcohol, and exposed to the low temperature. By this proceeding not crystals but an amorphous deposit of hematocrystalline is obtained from human blood and the blood of cattle collected in slaughter-houses. To such blood a modified process is best applied as follows:—The corpuscles are isolated by means of soda-sulphate or common salt, and then shaken with water and ether. After separation of the ether the red water-solution is treated with a solution of basic lead acetate as long as a precipitate ensues. This is removed by filtration; the excess of lead by a little potassium carbonate. To the filtrate powdered potassium carbonate is given until the hematocrystalline separates in grumous flakes. These are separated by filtration and strongly pressed. The cake is again broken and mixed with a little watery alcohol, which causes the separation of potassium carbonate in solution. Again strained and pressed the cake may be dissolved in water, and precipitated by alcohol, or by alcohol and cold.

Mode of obtaining amorphous cruorine.

Chemical composition of blood-crystals.

Chemical Composition.—According to the analyses of C. Schmidt and H. Seyler, the crystals from dogs, guinea-pigs, and geese have the following composition:—

	Dogs.	Guinea-pigs.	Geese.
C	53·64	53·85	54·26
H	7·11	7·32	7·10
N	16·19	16·17	16·21
S	0·66	0·39	0·54
Fe	0·43	0·43	0·43
O	21·02	21·84	20·69
P_2O_5	0·91	—	0·77
Alkalies	0·04	—	—
	100·00	100·00	100·00

Formula and molecular weight.

From these data the formula $C_{600}\ H_{960}\ N_{154}\ Fe\ S_3\ O_{177}$ has been calculated, leading to an atomic weight of 13280, far surpassing in magnitude that of any other molecule hitherto dreamed of in organic chemistry. While we may be quite certain that the atomic weight is very near that figure, we cannot determine it absolutely as yet for the following reason: the blood crystals retain more or less oxygen in loose combination like the blood itself, and yield it up in the vacuum, provided they are moist, but retain it the more tenaceously the dryer they are. We can determine the oxygen given off but we cannot as yet say whether any and how much oxygen is yet contained in the crystals in this particular form. Calculating from the quantity of iron contained in them as unit, we arrive at 13023 as the molecular weight.

Hematocrystalline combines readily and more pertinaciously than with oxygen with a number of other gases, such as carbonic oxyde, nitric oxyde, and hydrocyanic acid. It is peculiarly decomposed by sulphuretted and phosphuretted hydrogen, the latter agent producing a complete disappearance of all particular spectral phenomena. The study of its changes, which with so high an atomic weight, are probably extremely numerous, is therefore of paramount importance in pathological chemistry, and that the more so, as the muscles are also pervaded by hematocrystalline, and any change touching it in the blood may influence equally the whole or any part of the muscular system.

Spectral phenomena of hematocrystalline.

Spectral Phenomena of Hematocrystalline.—When a concentrated solution of hematocrystalline is placed before the slit of the spectroscope, and sun-light or lime-light employed for illumination, only some of the extremest red light is perceived in the spectrum. On continued dilution with water the illumination extends towards the D line, but before the region of this line has appeared clear, light is perceived in the green between the lines C and F. On continued dilution the extension of the light proceeds more towards F, and the dark region in the middle of the spectrum, which may now be called a band, contracts but slowly. But it ultimately allows light to pass over its middle, and is soon seen to consist of two bands. Of these the narrower, darker, and stronger defined one is situated towards the red close upon the D line, while the second wider, but paler one, is by the side of E. From this point the solution may be greatly diluted with the effect only of producing some shrinking in the width of the bands. But ultimately they become very pale, and when the solution has ceased to show any colour to the naked eye the bands also have completely disappeared. That these absorptions are properties of the blood circulating in the living body can be shown by experiment. Place the ear of a man or of a rabbit, or the closed commissure of the fingers, before the somewhat widely opened slit of the spectroscope in strong sun-light, and the bands will immediately appear. All red-coloured blood, in which the colour attaches to corpuscles as in vertebrata, or to the fluid as in the common earth-worm or the house-fly, yields these bands, and they are evidence that the matter imparting this red colour is identical in all, and is hematocrystalline. The spectrum can be seen upon thin sections of blood-clot, of muscle, or the thinnest layer of blood fixed upon glass in the manner in which microscopists are wont to preserve blood corpuscles. It can be seen upon the light reflected from a surface of blood, or upon single blood crystals, or by means of a spectroscope fixed to the eyepiece of an ordinary microscope, upon a single blood corpuscle.

Hematocrystalline does not easily putrefy.

The hematocrystalline is the last ingredient of blood which undergoes putrefaction; it preserves its colour and spectrum for years in a horribly offensive mixture, to which air has only moderate access. The putrefying blood evolves nitrogen and carbonic acid, and that with such tension that in one of my experiments it burst a bottle with explosive violence, by a collected pressure which could not have been less than 15 atmospheres. This kind of decomposition reminds of that which I found in cholera-stools, and described in the last report of the Medical Officer. The stability of hematocrystalline is the main factor in the stability of life. This quality is perhaps mainly the result of the power which it possesses of taking up oxygen from the air and yielding it again to other matter in contact.

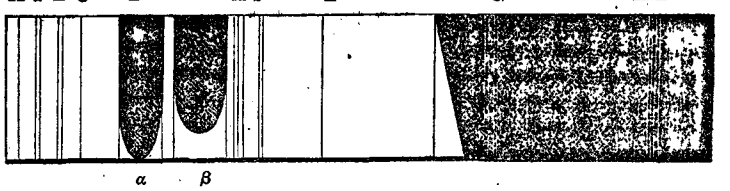
Spectrometric data.

The spectrum of blood, or hematocrystalline, is represented in fig. 1 of plate I. Measured repeatedly on my first spectrometer it shows :—

Band.	Measurements.	Width.	Intensity.	Rank.
1. Yellow to green -	141° 54′ — 141° 30′ =	0° 24′	10	α
2. In green -	141° 24′ — 140° 54′ =	0° 30′	8	β

There is green, feeble blue, cut off at 138° 54′.

*Intensity Diagram of Blood Spectrum.**



Quantitative determination of delicacy of spectrum as test.

A solution of hematocrystalline containing 2 per cent., examined in a layer of one centimetre in thickness, allows only the red part of the spectrum to penetrate. A solution of $\frac{1}{2}$ per cent. permits some green light to pass, diluted to $\frac{1}{4}$ per cent. it admits of the distinction of the two bands. A solution of 1 in 1,000 shows both bands already narrower ; they become still narrower on dilution, and disappear at a dilution surpassing 1 hematocrystalline in 10,000 water. From this it is evident that the delicacy of the spectroscopic test for blood is very great, and it has indeed been estimated, that if 5 cubic centimetres of water contain 0·00005 grammes of hematocrystalline, and are so arranged in a thin tube before the spectroscope that the light has to penetrate a thickness of the solution equal to 10 centimetres, they will yet yield the spectrum and give evidence of the presence of blood. This quantity is equal to 0·00775 grains, or say nearly $\frac{8}{1000}$ of a grain of hematocrystalline.

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* With the spectrum of the blood may be compared that of the blood-red feathers of the wings of the Cape Lory (*Turacus albocrystatus*), and of that of the alkaline

Diagram of Spectrum of Feather of Cape Lory.

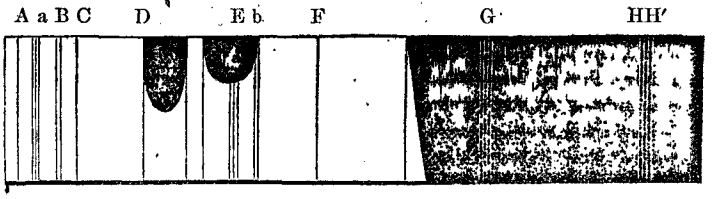
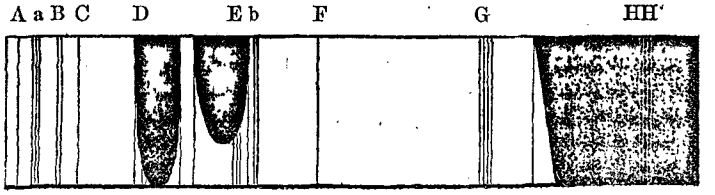


Diagram of Spectrum of Alkaline Solution of Pigment of the same.

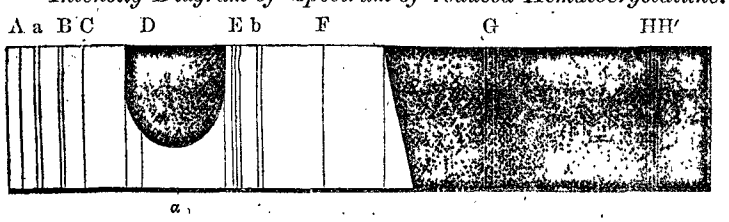


solution of their pigment, of which the general similarity to the spectrum of oxy-hematocrystalline is still greater (see Plate IV. figs. 9 and 10). This spectrum was discovered by Prof. Church, who found the pigment to contain copper.

Reduced hematocrystalline.

Reduced or Deoxydised Hematocrystalline.—The body described in the foregoing paragraph is the oxydised hematocrystalline, or arterial blood-colouring matter. By substances which attract oxygen this is easily changed, as was first shown by Stokes, into reduced hematocrystalline. Such reducing substances are serum, or serum diluted with water; hydrogen, and arseniuretted hydrogen; a solution of iron suboxyde sulphate in ammoniacal tartrate. When through a solution of blood in water which shows both bands well hydrogen with arseniuretted hydrogen is passed, and the fluid is allowed to be at rest a little while, and is thereupon placed before the spectroscope without being agitated or poured into another vessel, only one broad band is seen in place of the former two. It measures 141° 48′ — 140° 48′ = 1° 0′, spectrum cut off at 139° 23′ is therefore of the same width as, or perhaps 0° 6′ wider than that of the two oxydised blood bands, including the green space between them, but is moved a little more towards the violet end of the spectrum. Its intensity is only 8, and decreases more on the violet than the red side. When the solution is shaken up with air the one band disappears, and the two oxydised hematocrystalline bands reappear. The solution of iron suboxyde in ammoniacal tartrate is also very certain and handy, but it always yields a turbid spectrum, not to be compared in definition with the one obtained by the foregoing process. After oxydation by air the solution treated with iron has to be filtered to show the two blood bands again. It becomes quite black and impenetrable to light under certain circumstances. The spectrum of reduced hematocrystalline or venous blood is represented in plate I. fig. 2. Its intensity diagram is here subjoined.

Intensity Diagram of Spectrum of reduced Hematocrystalline.



Combination of hematocrystalline with carbonic oxyde.

Combination of Hematocrystalline with Carbonic Oxyde.—It has long been known that carbonic oxyde produces a particular change in the colour of blood, which is not destroyed by mixture with oxygen. It was shown that this was due to a combination of carbonic oxyde with hematocrystalline, which is always found when these bodies come in contact. The carbonic oxyde displaces oxygen, and remains attached to the hematocrystalline even in its crystals. The compound has almost the same spectrum as oxydised hematocrystalline, but the bands are situated a little more towards the violet end of the spectrum. By none of the means which reduce oxydised hematocrystalline can the bands of the carbonic oxyde hematocrystalline spectrum be changed or reduced. Upon the fixity of this combination, therefore, depends the fatal effect of carbonic oxyde when inhaled for any length of time. Further by the fixity of its spectrum can the compound be recognized, and consequently poisoning or suffocation by carbonic oxyde or charcoal vapour be diagnosed. The carbonic oxyde blood has a more bluish tinge than the venous or arterial.

Hematocrystalline and nitric oxyde.

Combination of Hematocrystalline with Nitric Oxyde.—Nitric oxyde, when passed into a solution of blood previously treated with hydrogen

or ammonia, expels oxygen as well as carbonic oxyde from their combination with hematocrystalline and combines with it. The absorption bands remain in the same places, although they are a little paler. The blood loses its power of being affected by reducing agents; but reduced solutions are made light red again by the nitric oxyde. The compound of hematocrystalline and nitric oxyde crystallises in the same forms as those with oxygen and carbonic oxyde.

Hematocrystalline and hydrocyanic acid.

Combination of Hematocrystalline with Hydrocyanic Acid.—This combination is obtained crystallised by addition of hydrocyanic acid to hematocrystalline solutions under the circumstances above related. It loses acid by recrystallisation. The compound is less stable than the two compounds just mentioned. By addition of deoxydising agents to the solution the spectrum of reduced blood is obtained. The spectrum of the combination shows no differences from the ordinary blood spectrum. It is of course natural to seek the poisoning action of hydrocyanic acid in its affinity for hematocrystalline. Experiments show, however, that this must be otherwise. For the blood corpuscles in cases of poisoning by this agent do not retain any of the acid, as they do when it is brought in contact with them directly. It must be abstracted from them again somewhere in the body. Hydrocyanic acid is the only acid which does not decompose hematocrystalline. All other acids immediately effect a cleavage into albuminous matter and hematine.

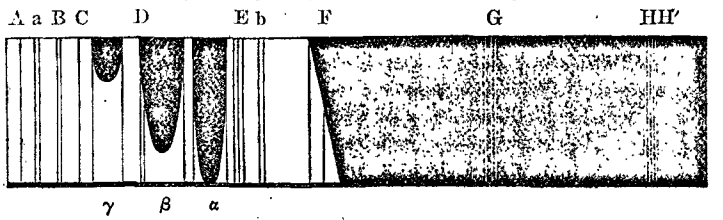
Influence of hydrothion upon blood.

Influence of Sulphuretted Hydrogen or Hydrothion upon Hematocrystalline.—Little hydrothion has no visible influence upon the spectrum. It passes through the circulation when injected into the rectum, and is exhaled unchanged by the lungs. But a concentrated solution or long-continued action changes the hematocrystalline completely. The blood bands disappear and three new bands appear instead, which have the following positions, intensities, and ranks:—

Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 12′ — 141° 55′	= 0° 19′	3	γ
2.	141° 42′ — 141° 18′	= 0° 24′	8	β
3.	141° 12′ — 140° 54′	= 0° 18′	10	α

The interval between 1 and 2 is remarkably yellow, even in a turbid solution which has stood for 24 hours. There is as yet no treatment known by which this substance can be again transformed into oxydised hematocrystalline.

Diagram of Blood treated with Hydrothion.



Some similarity to acid hematine disappears on comparison of the measurements. The peculiarity of the spectrum is very evident from its representation in fig. 7 of plate I. But it was found by Stokes that by reducing agents this body yielded the spectrum of reduced hematine. It may therefore be a solution of hematine in a peculiar acid, the nature of which remains to be investigated.

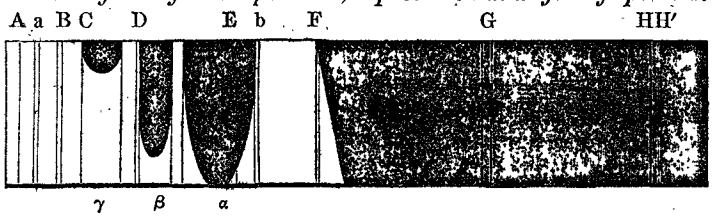
Blood treated with alcohol and ammonia.

Blood treated with Alcohol and Ammonia.—Blood was mixed with twice its volume of alcohol, and the coagulum filtered from the liquid. The latter showed no spectrum-bands. The coagulum dissolved in

ammonia showed a spectrum with three bands, which had a general resemblance to the sulphuretted hydrogen blood-spectrum, but showed very different measurements.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 18′ — 141° 54′	= 0° 24′	3	γ
2.	141° 42′ — 141° 24′	= 0° 18′	7	β
3.	141° 18′ — 140° 36′	= 0° 42′	7	α

Diagram of this Spectrum, represented in Fig. 8 of plate 1.



When this solution was mixed with alkaline iron protoxyde sulphate a spectrum of two bands appeared, which measured—

1.	141° 30′ — 141° 12′	= 0° 18′	int. 10.	α
2.	141° — 140° 42′	= 0° 18′	„ 3.	β

Blue end cut off at 140°.

This was therefore the reduced hematine spectrum, of which we shall find the details lower down.

Spectral phenomena of hematine.

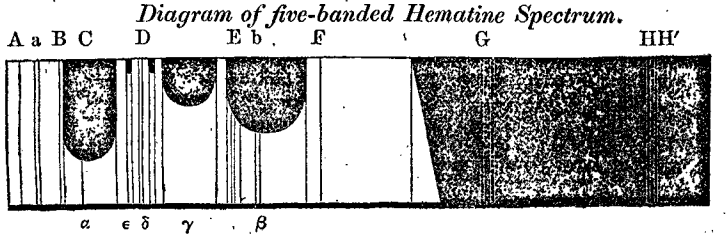
Spectral Phenomena of Hematine.—When hematocrystalline is treated with acids or alkalies and alcohol, it is split up into albuminous substances and a coloured matter, which retains all the iron, but none of the sulphur of the original compound. This is hematine. It appears from my researches that there are at least three different kinds of hematine recognizable by the spectroscope, besides a number of combinations which may be formed by one or perhaps all of them.

Five-banded hematine.

Five-banded Hematine.—Blood corpuscles isolated from serum by sulphate of soda in the manner above described are treated at the ordinary temperature with alcohol, to which a little sulphuric acid has been added. This solution was found by me to possess five absorption bands, three of them being those of acid hematine, first described by Stokes, two others being situated in red and orange, and narrow, one very fine, like a narrow bundle of sun-lines.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	46 to 56	10	7	α
2.	58 to 60	2	1	ε
3.	64 to 70	6	1	δ
4.	79 to 96	17	3	γ
5.	98 to 117	19	5	β

Diagram of five-banded Hematine Spectrum.



The bands 2 and 3 are best seen in the non-magnifying spectroscope with a sulphide of carbon prism, and a good gaslight. The

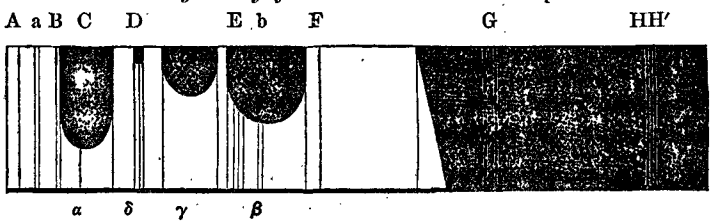
magnifying spectroscope with flint-glass prisms shows them less distinctly.

Four-banded Hematine by a modified Process.—When the corpuscles are boiled in water after treatment with sodium sulphate, so that all sulphate is removed, and are then treated with acidified alcohol, a solution is obtained which gives a spectrum similar to the former by its three lines, 1, 4, and 5, or α, β, and γ, but instead of ε and ζ there is only one line midway between the places occupied by the two. This is identical with the spectrum of hematine first described by Stokes. It was also obtained by dissolving pure crystallised hematine in alcohol and little sulphuric acid by the aid of a gentle heat.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	41 to 55	14	7	α
2.	61 to 64	3	1	δ
3.	74 to 93	19	3	γ
4.	96 to 120	24	5	β

End of blue at 157. The interval between the band 3 and 4 is very obscure. Band 2 in Drummond's light became in thick solution rather stronger, measuring 63 to 72=9.

Diagram of four-banded Hematine Spectrum.



Acid hematine in water.

Blood treated with Acid.—The simple addition of acid to blood changes its spectrum. When an organic acid, such as acetic or tartaric, is taken, one band in red appears, and great obscuration of the rest of the spectrum ensues. The one band in red belongs to acid hematine, and the darkness in green is due to two other bands. These, first correctly described by Stokes, it is not easy to define without the aid of sunlight or Drummond's light. They have therefore not been noticed by later authors. Upon the purest specimens of acid hematine they can, however, be observed and measured with tolerable accuracy. The acid solutions of hematine were hitherto believed to contain a particular body, which was termed hemine. It is, however, quite easy to show that it is hematine, for its spectrum can by alternate acidification and alkalification be made to yield the bands either of acid or alkaline hematine. The following measurements were observed upon tartrate of hematine :—

Band.	Measurements.	Width.	Intensity.	Rank.
1 in red	142° 30′ — 142°	= 0° 30′	8	α
2 in green	141° 30′ — 140° 58′	= 0° 32′	3	β
3 do. to blue	140° 54′ — 140° 6′	= 0° 48′	5	γ

Alkaline hematine.

Alkaline Hematine.—In order to fully study the phenomena of hematine I produced a quantity of it in a neutral state. A large quantity of amorphous hematocrystalline was made from 10 gallons of blood and a hundredweight of potassium carbonate. The isolated material was dried at 40° C, and extracted with cold absolute alcohol. The splendid ruby red solution was treated with a solution of tartaric acid in absolute alcohol as long as a precipitate fell down. The filtered

Pure crystallised hematine.

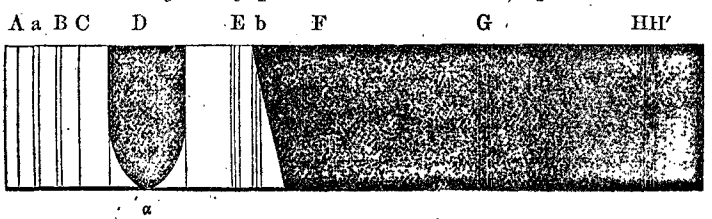
solution was then slowly evaporated at 40° C., until it deposited all colouring matter as a fine powder of black, somewhat violet, colour. This was filtered off, the powder washed with alcohol, lastly with water. It was then redissolved in absolute alcohol and potassium carbonate. Tartaric acid was again added, and crystallisation completed as before. Ultimately a black violet powder remained, consisting under high powers of the microscope of little rhombic scales, mostly crossed and imitating well the shape of the hemine crystals. I believe this to be pure crystallised hematine. It certainly contained no hydrochloric acid, and negatived the assumption hitherto made by some animal chemists, that all crystallised hematine was identical with hemine, and like hemine was a hydrochlorate of hematine. I reserve communication of the chemical analyses of this substance for future opportunities, and confine myself to the spectral phenomena offered by this matter. For I have shown above that what different authors term hematine are different substances. It is thereby explained why each new inquirer should have found results differing from those of his predecessors. Thus the iron in hematine was ascertained to be, by

Mulder	- - -	6·7 per cent.
Le Canu	- - -	7· ,,
Rollet	- - -	7·2 ,,
F. Simon	- - -	8·2 ,,
Hoppe Seyler	- - -	8·9 ,,

The latter author, who had declared crystallised hemine to be a hydrochlorate, has just retracted his statements regarding hematine.

The neutral hematine is insoluble in water, alcohol, and ether, but dissolves in caustic alkaline water and in alkaline or acid alcohol. The spectrum of the acid solution is that just described. The alkaline alcoholic solution described in my cholera report had the following spectrum :—Red very vivid, band from orange to near green 142° 24′ — 141° 36′ = 0° 48′, the terminal towards green being with difficulty determined on account of the green being very much shaded. The spectrum cut off entirely at C; when diluted it measured 142 °18′ — 141° 42′ = 0° 36′, or 142° 18′—141° 48′ = 0° 30′, but the pure hematine in alkaline alcoholic solution now produced shows a somewhat different spectrum. Band 142° 0′ — 141° 16′ = 0° 44′. Intensity 8 = α.

Diagram of pure alkaline Hematine Spectrum.



The band is therefore broader and in a different position from that formerly described. The causes of this difference remain to be investigated. Treated with a little sulphuric acid the spectrum immediately becomes that of acid hematine. β very indistinct but dark, γ with a decided red tinge. The margin on the blue side most difficult to read, but there is a decided blue interval between it and the final darkness.

Band.	Measurements.	Width.	Rank.
1.	142° 18′ — 141° 54′ =	0° 24′	α
2.	141° 12′ — 140° 48′ =	0° 24′	β
3.	140° 42′ — 139° 54′ =	0° 48′	γ

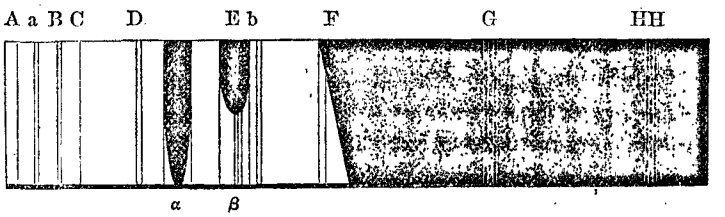
Reduced Hematine.—When an alkaline watery solution of hematine is mixed with a deoxydising agent such as the alkaline tartrate solution of ammonio-sulphate of iron suboxyde, the former spectrum gives way to a new one, showing two bands. See fig. 6, plate I.

Band.	Measurements.	Width.	Intensity.	Rank.
1.	141° 30′ — 141° 12′ =	0° 18′	10	α
2.	141° — 140° 42′	0° 18′	3	β

Blue cut off at 140°.

Reduced hematine.

Diagram of reduced Hematine Spectrum.



This body was first produced and its spectrum observed by Stokes, "The two bands are situated at about the same distance apart as those "of oxy-hematocrystalline, and are no less sharp and distinctive. They "are a little more refrangible, a clear though narrow interval interve-"ning between the first of them and the line D. They differ much from "the bands of oxy-hematocrystalline in the relative strength of the first "and second band. With oxy-hematocrystalline the second band appears "almost as soon as the first, on increasing the strength or thickness of "the solution from zero onward, and when both bands are well developed "the second band is decidedly broader than the first. With reduced "hematine on the other hand, the first band is already black and intense "by the time the second begins to appear. Then both bands increase, "the first retaining its superiority until the two are on the point of "merging into one by the absorption of the intervening bright band "when the two appear about equal. Like hematocrystalline reduced, "hematine is oxydised by shaking up its solution with air."

Cruentine, a derivate of hematine.

Cruentine, a new derivate of Hematocrystalline and of Hematine.—When human or animal hematocrystalline is boiled with sulphuric acid it becomes chemolysed, the albumen dissolves and yields its particular products, a portion of the hematine also dissolves and colours the fluid ruby red, while a brownish red grumous matter remains suspended in the fluid in an insoluble state. This is a mixture of neutral cruentine with its sulphate. By washing with water this matter loses sulphuric acid, and becomes ultimately free from it. Treated with sulphuric acid it dissolves completely, and is now sulphate of cruentine.

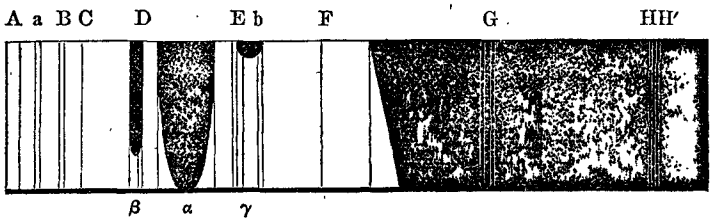
Cruentine sulphate.

Cruentine Sulphate.—When a concentrated solution of this body is examined with the spectroscope it shows one broad black band, in red to orange 142°—140° 30′=1° 30′, blue cut off at 139° 36′. The visible blue is about as extensive as the visible green. On dilution this band splits up into two, and a third very feeble band in green becomes visible just to disappear. We have thus a spectrum of three bands.

Bands.	Measurements.	Width.	Intensity.	Rank.
1 in yell. & orange	142° — 141° 50′	— 0° 10′	8	β
2 green	141° 30′ — 141° 8′	— 0° 22′	10	α
3 green	140° 48′ — 140° 30′	— 0° 18′	2	γ

The order of intensity of these bands is not the same in all dilutions. There is a point when γ is just visible, intensity 1, at which α and β are of equal intensity, while just before the dilution at which γ appears the first band, 1, is decidedly most intense. On continued dilution, however, the first band disappears before the second. The absorption is at all times equal to that of blood, so that when the fluid shows the merest tinge of pink the bands are yet clearly visible.

Diagram of Spectrum of Sulphate of Cruentine.



This diagram illustrates the intensity of the bands of figure 9, plate I.

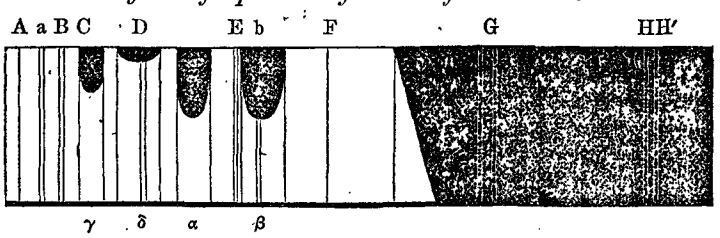
Neutral fluorescent cruentine.

Neutral fluorescent Cruentine.—When the insoluble residue from the sulphuric acid treatment is washed to neutrality and dried, a portion of it is soluble in ether and chloroform. The ether solution has four bands, which are a little paler than, but as nearly as can be identical with, the bands of the chloroform solution. This latter prepared by boiling is dark red, and shows spectrum—

Bands.	Measurements.		Width.	Intensity.	Rank.
1.	142° 18′ — 142° 3′	=	0° 15′	3	γ
2.	141° 55′ — 141° 30′	=	0° 25′	1	δ
3.	141° 21′ — 141°	=	0° 21′	5	α
4.	140° 45′ — 145° 18′	=	0° 27′	5	β

Blue dark, cut off at 139° 9′.

Diagram of Spectrum of neutral fluorescent Creuntine.



The saturated chloroform solution was one Ctr. thick. The spectrum was measured with the aid of a gaslight only. It fluoresced with a splendid blood-red colour in the sun-cone. This is the first body which is known to fluoresce with homogeneous light, that is to say, the same kind of light or colours which it transmits. The fluorescent cone has an intensity of colour equal to that of a solution about ten times more concentrated. Considering its beauty alone the phenomenon may be placed by the side of those exhibited by quinine, chlorophyll, or cudbear. But by its peculiarity it is perfectly unique.

Alkaline Four-banded Cruentine.—Spectrum 11, plate II., represents

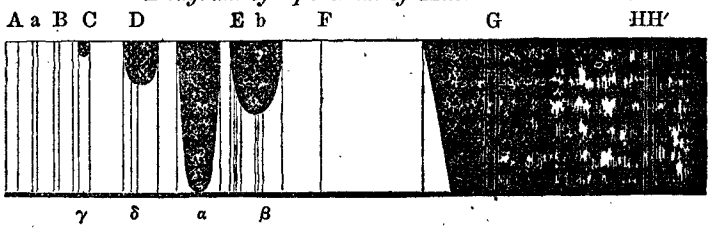
solution in alcohol of cruentine made alkaline by ammonia. It measured—

Alkaline four-banded cruentine.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 15′ — 142° 6′ =	0° 9′	1	δ
2.	141° 48′ — 141° 30′ =	0° 18′ feeble	3	γ
3.	141° 18′ — 140° 54′ =	0° 24′ strongest	10	α
4.	140° 48′ — 140° 15′ =	0° 33′	5	β

Cut off at 138° 51′. Violet appears a little.

Diagram of Spectrum of Alkaline Cruentine.



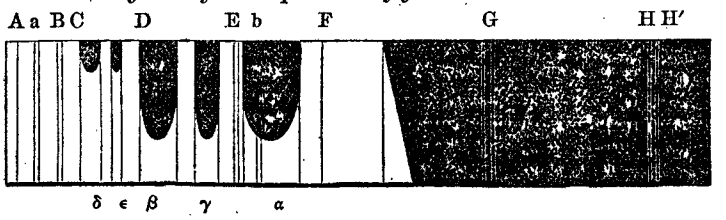
Neutral five-banded cruentine.

Neutral five-banded Cruentine in Alcohol.—When the preparation from which chloroform extracts the neutral fluorescent cruentine is treated with alcohol, it dissolves easily and almost entirely. The concentrated solution allows a little red to pass; on further dilution three bands appear, ultimately five, one in red feeble, one in yellow also feeble, both narrow, and three dense and dark bands in green, the last one situated at the point of transition into blue.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 18′ — 142° 6′ =	0° 12′	2	δ
2.	142° — 141° 54′ =	0° 6′	2	ε
3.	141° 42′ — 141° 21′ =	0° 21′	7	β
4.	141° 12′ — 140° 58′ =	0° 14′	7	γ
5.	140° 45′ — 140° 12′ =	0° 33′	7	α

Cut off in blue at 139° 24′. (See fig. 10, plate I.)

Diagram of the Spectrum of five-banded Cruentine.



When this solution is made alkaline with ammonia the band 2 disappears, and the others arrange themselves slightly differently, as stated above under neutral cruentine. Band 1 remains in its place, but loses a little on the red side. It measured—

In the primary alcohol solut. 142° 18′ — 142° 6′ = 0° 12′
After addition of NH_3 - 142° 15′ — 142° 6′ = 0° 9′

Band 3 of primary solution also becomes feebler and narrower.

It measured - - 141° 42′ — 141° 21′ = 0° 21′
After addition of NH_3 - 141° 48′ — 141° 30′ = 0° 18′

Band 2, which disappears, coincides with band 1 of acid cruentine sulphate, as the comparison of their measurements will show.

Acid cruent. sulph. β - -	142° — 141° 50′	= 0° 10′
Band 2 of above spectrum -	142° — 141° 54′	= 0° 6′

These considerations admit of some application to the explanation of the spectrum just described. The body is either a neutral dibasic sulphate, or is a mixture of acid sulphate and neutral sulphate, the spectra of which are intermixed, or as it is termed, superposed upon each other. To this latter explanation there is, however, this weighty objection, that the mixture, a five-band body only, is soluble in alcohol, while the four-band body is not soluble in alcohol. Acid cruentine is, however, easily soluble in alcohol. If, therefore, the alcoholic solution contains acid and neutral cruentine, the latter is only dissolved by means of the acid salt, but without loss of its spectrum.

The five and four banded cruentine are both transformed into the three-banded acid cruentine by solution in sulphuric acid. On addition of water the five-banded cruentine is again obtained, which by ammonia becomes four-banded.

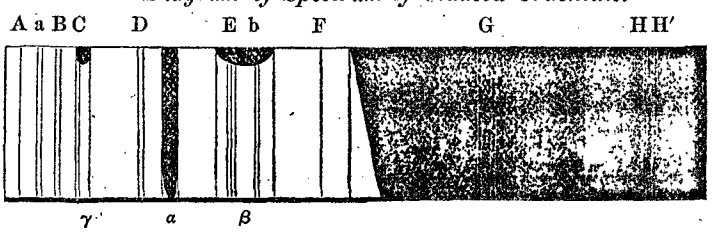
The five-banded cruentine was obtained by extracting with ether and much glacial acetic acid, cruentine many times dissolved in sulphuric acid, and re-precipitated by water. Immediately on washing out the acid by water one band in orange disappeared, the red was more intense, and in fact the ether showed the four-band cruentine spectrum.

Reduced cruentine.

Reduced Cruentine.—Cruentine dissolved in ammonia shows the four bands. When an ammoniacal tartrate solution of iron suboxyde is added to it, it changes its spedtrum in the following manner (see spectrum, fig. 2, plate II.): There is a pale band 1, in red; possibly there is a shadow in yellow to green, where a rather abrupt transition occurs. There is a prominently dark band, 2, in green, and a broader one, in green towards blue.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 21′ — 142°	12′ = 0° 9	1	γ
X. if existent, a mere line.				
2.	141° 30′ — 141°	18′ = 0° 12′	10	α
3.	141° — 140°	26′ = 0° 26′	2	β

Diagram of Spectrum of reduced Cruentine.

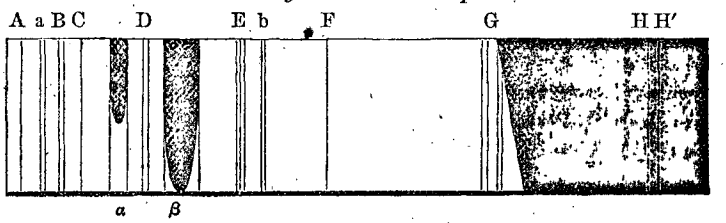


On being shaken with air the solution becomes much lighter, and presents again the spectrum of four-banded cruentine.

When the solution of reduced cruentine is acidified with sulphuric acid it yields a precipitate. After filtration it is much lighter and passes very clear of a pale rose tint. Its spectrum shows the bands represented in fig. 3, plate II.

Band.	Measurement.	Width.	Rank.
1.	142° — 141° 50′	= 0° 10′	β
2.	141° 30′ — 141° 8′	= 0° 22′	α

Diagram of Spectrum of acidified Solution of reduced Cruentine, being Cruentine Sulphate.



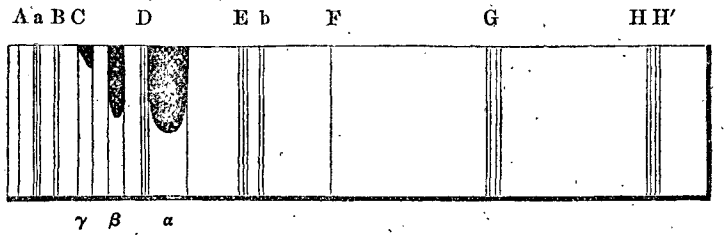
These are the bands of acid cruentine in the dilution where γ has completely disappeared. Cruentine therefore exhibits this peculiar property, that it can be deoxydised (in alkaline) and reoxydised (in acid) solution. During this process, however, much colouring matter is lost by changes not yet scrutinized. In its alkaline solution it is desoxydised and reoxydised as easily as hematocrystalline. It is a most remarkable fact in science that a decomposition product of hematocrystalline of the second order retains what I will term the breathing power of the blood corpuscle.

Cruentine and Hydrochloric Acid.—The chloroform solution treated with HCl and water becomes turbid. Warmed, it clears up and appears more rose-coloured. On cooling it becomes, however, again turbid. Its spectrum shows three bands. Cruentine and hydrochloric acid.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	? — 142° 12′ =	?	3	γ
2 in yellow	142° 3′ — 141° 54′ =	0° 9′	5	β
3 in green	141° 39 — 146° 18′ =	0° 21′	7	α

Green not shaded, blue entire, but appears green. The margins of β are sharper than those of α.

Diagram of Hydrochloric Product of Cruentine.

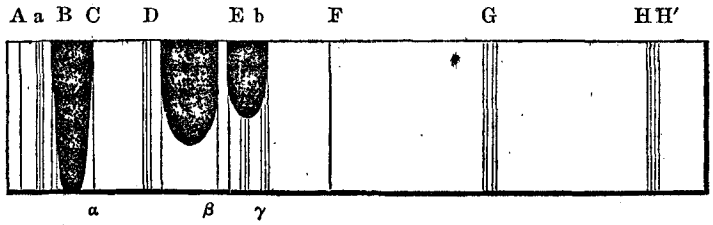


The hydrochlorate was over-saturated with NH_3 and warmed. The three bands remained the same. The ammoniacal solution was faintly coloured. Ammoniated water did not extract the coloured matter. It is therefore clear that hydrochloric acid effects a permanent change in cruentine.

A combination of calcium-cruentate when decomposed by HCl and extracted by chloroform yielded another spectrum of three bands. Second hydrochloric product.

Band.	Measurement.	Width.	Rank.
1 in red	142° 36′ — 142° 12′ =	0° 24′	α
2 in green	141° 33′ — 141° =	0° 33′	β
3 do.	140° 54′ — 140° 30′ =	0° 24′	γ

Diagram of this Spectrum of second Hydrochloric Product of Cruentine.



Interval between 2 and 3 very dark. Blue side of 3 estimated only. Blue not clear, but very shady; end of spectrum not to be clearly ascertained.

Acetate of cruentine.

Cruentine from the human body had been repeatedly treated with sulphuric acid for the purpose of extracting the iron in the manner first proposed by Mulder. It was dissolved in NH_3, and yielded the four-band spectrum above described. On addition of acetic acid and boiling the band in the red disappeared, and then a flaky precipitate formed. When the latter had been separated by filtration the filtrate no longer showed any bands. Consequently the cruentine was precipitated by acetic acid from ammoniacal sulphate and acetate solution. The precipitate dissolved in alcohol. It appeared to contain acetic acid. Its spectrum is represented in fig. 14, plate II.

Hematine free from iron.

Note on supposed Hematine free from Iron.—Cruentine from human blood was dissolved in concentrated sulphuric acid, and after standing re-precipitated by water; a quantity always remained in solution and was lost. After 16 operations of this kind, repeated upon one and the same specimen, this was dissolved in ammonia and evaporated to dryness, when it lost all ammonia and became similar to uromelanine in external appearance. On analysis it yielded 1·51 per cent. of iron. From this experiment it has become very questionable whether iron can be entirely removed from hematine by this proceeding.

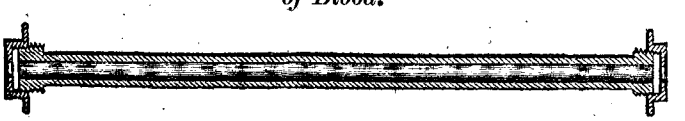
Cruentine and dichromate.

When the acid solution of cruentine is treated with some potassium-dichromate, it becomes much lighter and the bands disappear completely from the spectrum; but the chemical nucleus contained in hematine resists this treatment and all others with great pertinacity, and products are obtained which, though lower in the molecular scale than hematine and cruentine, are nevertheless, comparatively speaking, of great atomic complication.

Discovery of blood in medico-legal cases.

Discovery of Blood in medico-legal cases.—The spectroscope has greatly increased the means of discovering blood, particularly in cases where attempts have been made to destroy its traces by washing or otherwise. The articles to be investigated are soaked in tepid water of 40° C. temperature, and the solution is placed in a sufficiently thick layer before the slit of the spectroscope. In order to obtain the thickest possible layer with the minimum amount of fluid it is requisite to use

Section of Tube for Spectroscopic Examination of dilute Solutions of Blood.



tubes of small diameter, which can be closed at both ends by parallel pieces of plate-glass fixed to the tubes by means of screws. Such tubes

are always used in polariscopes, and are therefore to be found in every laboratory, but for the particular purpose of spectrometry two or three of different lengths should be at hand.

If the extract of the articles to be examined shows the faintest coloration, blood-bands may appear. If they do not, and if the water used in the extraction was necessarily a large quantity, its bulk has to be reduced to a minimum by evaporation in vacuo over sulphuric acid. When the blood-bands do appear it may be concluded with certainty that the articles examined contained some blood or hematocrystalline from a vertebrate animal or a human being. But the test gives no information on the question whether the blood is human or animal, and from which class of animals it comes. When the extract exhibits no bands it is certain that the articles extracted contain no unaltered blood; but it is by no means certain that altered blood may not be contained in them. This has to be tested by the methods which the spectroscopic phenomena of hematine and cruentine now put at our disposal. There are two particular cases in which the blood adhering to clothes or other articles becomes so altered that it can no longer be recognized by the means hitherto at the command of medico-legal analysts. 1. The articles have been boiled in water. In that case the hematocrystalline is coagulated and insoluble. 2. The articles have been washed and dried at a heat which destroys any hematocrystalline which may have remained in them. Sometimes the hematocrystalline is peculiarly changed without the interference of heat by causes at present unknown. In such cases the articles should be macerated with alcohol which has previously been saturated with carbonate of potassium. All hematine will be dissolved out, and on concentration of the solution on the waterbath at 40° C. will yield a red solution, which gives the alkaline hematine spectrum above described. On addition of acetic or tartaric acid this spectrum will give way to the acid hematine spectrum. When the alcohol is evaporated, and a watery alkaline solution obtained, the hematine may be subjected to the reduction test. The hematine may then be concentrated and dissolved in concentrated sulphuric acid. With this solution all the tests for cruentine above described may be obtained. Two or three of these tests, particularly the change from alkaline to acid hematine, are quite sufficient to prove the identity with hematine from blood.

All these examinations can be carried out with the aid of the ordinary spectroscope, which, with the precautions mentioned, will indicate the presence of the most minute quantities of matter. This particular research can also be carried out by attaching the spectroscope to a microscope in the manner excogitated by Messrs. Sorby and Browning. The phenomena to be observed show great intensity and definition. But the spectra of such microspectroscopes, although they can be compared with standard spectra placed by their side (which can also be done with the same facility in the ordinary spectroscope), cannot be measured with anything like the degree of accuracy obtainable by my new method of spectrometry above described.

The precautions against error are of course to be observed with the utmost rigour. All dyes and other matters which can possibly interfere, either by simulating blood, or, what is much easier, by hiding its presence, must be carefully eliminated. For this purpose the general spectroscopic reactions of the most important dye-stuffs given above will be found useful.

V.—ATOMIC WEIGHTS AND DECOMPOSITIONS OF THE ALBUMINOUS SUBSTANCES.

Albuminous substances most condensed.

The most condensed substances are those which constitute the human body. Brain substance, hematocrystalline, fibrine, albumen, have atomic weights varying between 20,000 and 1,612, more or less; that is to say, the sums obtained by the multiplication of the number of atoms of each element with the atomic weight of that element, and by subsequent addition of these products, amount to figures varying between 20,000 and 1,612. Now, as no chemistry is perfect without the knowledge of the atomic weight of substances dealt with, so no attempt at pathological chemistry can be perfect, or lead to important results, which does not base itself upon the atomic weights of the normal substances of the body, and uses them as a measure for determining the atomic weights of the abnormal ones. The comparison shows the amount of change, and if all stages of the change be known or deducible, the nature of the change, that is, the pathological process.

If it were necessary to study the changes of the albuminous matters upon substances only which have resulted from actual pathological processes in living beings, the difficulties of the task would be enormous. For these products are of only transient existence, most of them are as completely consumed or oxydised as the normal substrata; to collect them in quantity sufficient for atomic determination would require hundreds or thousands of operations; in many cases it would be impossible to collect them at all. Under these circumstances chemical methods are applied to the albuminous substances out of the body, by which they are variously decomposed; the products are analysed, and their properties and reactions so well determined, that if they afterwards are met with in pathological products they can be at once identified. These methods are termed *physiolysis* and *chemolysis;* the health standard of comparison is termed *biolysis,* and the process of disease which they are to illustrate is termed *patholysis.* Of biolysis a sketch has been given in a previous chapter. From assimilation to the intermediate cleavage effected by the biliary function, and from this to the final excretion of multifarious products by urine and breath we have seen a connected chain of chemical (synthesis as well as) lysis. Under the term physiolysis we imply a solution of animal substances into proximate nuclei or final products under the influence of the natural agents oxygen, moisture, and heat, in the presence of more or less water. This process, when occurring without regulation under the influence of atmospheric influences is termed putrefaction; but physiolysis means putrefaction regulated by certain designs and precautions, which may preserve proximate products from destruction, collect such as are volatile, and on the whole keep the process as uniform as possible. Chemolysis on the other hand is the artificial and mostly rapid decomposition of animal matters into proximate nuclei by means of chemical agents, which do not themselves undergo any change, but only combine for a time with some of the products, and may ultimately be removed entirely. Hot water, particularly under high pressure, alkalies in water, acids, particularly hydrochloric and sulphuric, have all this chemolytical power. In ordinary experiments sulphuric acid is mostly used, on account of its non-volatility and the possibility of removing it from the solution more completely than other agents. The application of these methods has led to the remarkable result that the products of both physio-and chemolysis do not resemble those of biolysis at all, but resemble those of patholysis; and again, that the products of chemolysis resemble more to those of patholysis than to those of physiolysis, or in other words, that a

Physiolysis.

Chemolysis.

sick body is more in the condition of being dissolved in sulphuric acid than in that of being putrefied. But there are exceptions to this, in which putrefaction is closely imitated by the patholytical process. It remains to observe that temperature is a great factor in the sum of results which may be obtained by either process. In the dilute sulphuric acid solution the temperature rises little above that of boiling water; in regulated putrefaction a very low temperature 12° to 19° C. is mostly observed; while in diseases such as fevers a higher temperature, and in others such as cholera a lower temperature, than the normal (max. 38° 6 C., min. 36° 76, mean 37° 6 C.) one is kept up. We cannot doubt that the special dynamicities of the elements of the body are in part at least determined by its temperature, and *vice versâ*, that pathological influences change the dynamicities and consequently the temperature.

Influence of temperature upon lysis.

The mere percental composition of the albuminous substances, albumen, fibrine, and caseine, is almost identical in all three, and would lead to one and the same formula. Nevertheless they differ so much in their chemical behaviour, and in their origin, as far as that is known, that there must be essential differences determinable only by atomic or molecular weight determinations. The silver and zinc compounds of albumen had led Lieberkühn to adopt 1612 as the molecular weight and $\mathfrak{C}_{72}\ H_{112}\ N_{18}\ \mathfrak{S}\mathfrak{O}_{22}$ as the formula of albumen. The researches of Schwarzenbach by means of the platino-potassic cyanide had apparently led to the same result. I therefore repeated these experiments. The platino-potassic cyanide was prepared by dropping a concentrated solution of platinic chloride into a concentrated solution of potassic cyanide, and heating the mixture until the precipitate which formed at first was redissolved. The platinic chloride was reduced by the cyanogen to subchloride, as evidenced by the escape of ammonia carbonate, and nitrogen. On cooling the salt crystallised; it had to be recrystallised. Other modes were also tried, but considered still less satisfactory and more expensive than the foregoing one. The formula of this salt is—

Molecular weight of albumen.

$$2\,(K\ \mathfrak{C}y) + \mathfrak{P}t\ \mathfrak{C}y_2 + 3\,(H_2\mathfrak{O}).\quad (\mathfrak{C}y = \mathfrak{C}N)$$

In the researches of Schwarzenbach, this salt, when dropped into a solution of albumen previously acidified with acetic acid, produced an insoluble white precipitate, a compound of albumen and platinic cyanide. This left on an average 5·56 per cent. of $\mathfrak{P}t$, leading to 3,236 as the molecular weight of the albumen combined with it. The atomic weight of albumen as given by Lieberkühn and doubled in accordance with the requirements of the didynamic character of the $\mathfrak{P}t$ atom, is 3,224, which differed so little from 3,236 that it could be considered identical with it. But in my own analyses an average of 5·34 per cent. of $\mathfrak{P}t$ was found, which divided by the atomic weight of $\mathfrak{P}t$ (197·4) gave a quotient of 0·0270 instead of the 0·0283, the one required by the theory of Schwarzenbach. This destroyed at once the proportions between $\mathfrak{P}t$ and albumen, and caused me to abandon the research as not likely to lead to final information. Since that time my apprehension has been confirmed by two events. The first are researches by Diakonow, which make it very probable that the irregularities in the composition of the platino-cyanide precipitates of albumen may be still greater than I had found them; and the second is that Schwarzenbach has retracted his statement about the atomic weight of caseine being half that of albumen. The effect of all these analyses and discussions is that inquiry is anew directed to the methods which I have adopted in the following for getting at the atomic weight of the albuminous substances.

Physiolysis of Fibrine.

Decomposition of fibrine.

Yields albumen.

As the products of putrefaction take a considerable share in the effects of wounds and dyscrasias their study was continued upon fibrine. The fibrine was allowed to decompose in its wet state, without any additional water, in loosely covered glass vessels in a cool place. On analysis it yielded many of the matters already described by Bopp, and in addition some new ones. The fibrine had deliquesced, and its watery solution with some acetic acid and boiling yielded albumen This phenomenon goes far to support the theory of the formation of fibrine above related, according to which it contains two albuminous nuclei, and would therefore have an atomic weight of about double that of albumen. But as other derivations are not excluded, and the formation of fibrine as well as its physiolysis have never been investigated quantitatively, no certain deductions can be made. Caseine or boiled flesh yield no soluble albumen by physiolysis. The fluid derived from the decomposed fibrine by mixing with water was turbid, contained myriads of infusorial beings, particularly vibriones, and a suspended organic matter, which made filtration almost impossible. From this I extracted cholesterine by alcohol. This might possibly be derived from some white blood corpuscles, which it is almost impossible entirely to exclude from the fibrine, but its quantity seemed to be greater than this surmise could account for. By treatment with lime volatile alkalies,* particularly ammonia and trimethylamine, the latter in small quantity, were evolved, accompanied by a crystalline matter which was soluble in ether and had a powerful and disagreeable odour. By treatment of the residue with acid, valerianic, butyric, and a small quantity of other acids were obtained. From the fluid I extracted, with ether, a brownish red oil, soluble in hot, insoluble in cold water, soluble in spirit, which was an acid, and formed a pitchlike salt when treated with lead acetate. From the evaporated fluid leucine was extracted, then there remained a syrup, which was soluble in alcohol and precipitated by ether, dissolved earths and acids like the syrupy acid (fluorescentic acid, see below) obtained by sulphuric acid chemolysis of albumen, but was distinguished from it by yielding with sulphuric acid tyroine. This latter body therefore remains longer attached to the original main nucleus in putrefaction than in chemolysis. The most important of the above products of this research were destroyed by an incipient conflagration which unfortunately took place at the laboratory during a hot summer noontide.

Other products.

Chemolysis of Albumen.

Chemolysis of albumen.

The decomposition of albumen by artificial chemical means or chemolysis is a more practical way than the former, as being less disagreeable to the senses of the operator and requiring less time. I have repeated and amended almost every known process, and on that account alone the results would possess some value. They claim, however, more attention on account of the discovery of six well-defined new and highly interesting chemical compounds, which I will shortly describe.

Of materials, fibrine, albumen, and yelk of egg, caseine, blood, cows, and human hair, camels' hair, horn shavings and horn dust, and a great

* Some years ago Crace Calvert announced in the Proceed. Royal Soc. that he had obtained from putrefying meat and fish, volatile alkalies containing sulphur and phosphorus. In my researches I have never met with such volatile alkalies, and think it very questionable whether they do actually exist. The volatile crystalline matter may contain sulphur and phosphorus, but is not an alkali.

variety of human and animal organs were employed. As decomposing agent I mostly used sulphuric acid, but also caustic potash. By the acid treatment there was obtained a brown substance, soluble somewhat in acids, easily in alkali, reprecipitated by acetic acid in brown flakes, which when dry form a brownish black powder. (Possibly fluopittine, defined below, may stand in some relation to this brown matter.) It is questionable whether it corresponds to the insoluble matter suspended in putrefying albumen and fibrine. A small quantity of volatile acids was obtained and combined with barium. They have not yet been analysed any further. Next large quantities of volatile alkalies were collected. These consisted mainly of ammonia, but a peculiar smell of seafish, and blackening of the salts on evaporation, led to further scrutiny, whereby some trimethylamine, C_3H_9N, was isolated. (Platinum in the chloride combined with platinic tetrachloride=37·20 per cent.) By repeated extraction with alcohol, and recrystallisation and reprecipitation with platinic chloride, salts were successively obtained which contained 39·20 per cent. Pt, 39·14 per cent. Pt, and corresponded to dimethylamine-chloride-platinic chloride. A salt was further obtained yielding 42·56 per cent. of Pt, being nearest to the theory of monomethyl ammonium Cl Pt Cl_4, which requires 41·87 per cent. of Pt. Further a compound was frequently obtained containing 42·23 per cent. to 42·28 per cent., 42·85 per cent., 42·0 per cent. of Pt, and corresponding to a salt or mixture in atomic proportions of 1 atom of trimethyl-ammonium—chloride—platinic chloride, and 3 atoms of ammonium—chloride—platinic chloride. In most of these salts the carbon and hydrogen were also determined by elementary combustion. I am of opinion that the immediate products of the chemolysis of the albuminous matters contain far more complicated alkalies than those above obtained. During the boiling with lime large quantities of gas of peculiar smell are constantly evolved, being volatile hydrocarbons not absorbable by water or acid. The condensed hydrochlorates of the alkalies become black during every evaporation. Consequently a decomposition is constantly taking place, leaving ultimately pure ammonia. We shall see that neurine, a base obtained from brain-matter, yields by decomposition trimethylamine, and can be artificially prepared from it. I have no doubt that albuminous matters as well as cerebric acid yield neurine, and that the compound ammonias above described are derived from some such proximate product of decomposition. A most remarkable product of this chemolysis was a new alkaloid, to which, from its most striking power of fluorescence, I gave the name of fluorescentine. This is a white solid, deposited in little rosettes of leaves and globules. It is little soluble in water, little soluble in ether, more easily soluble in alcohol. It dissolves easily in dilute sulphuric and other acids, and is precipitated from this solution by iodine in crystalline needles of green and gold colour. It is quickly altered by even moderate heat, least in its watery sulphuric acid solution, most in a concentrated alcohol solution when it is evaporated on the steam bath. Its power of fluorescence (violet blue) is not destroyed by any solvent, acid or alkali, which does not absolutely destroy the substance itself. Accompanying fluorescentine is a substance termed parafluine, which is red, amorphous, readily soluble in alcohol and ether, but insoluble in water and dilute sulphuric acid. It is accompanied by a matter having a powerful odour, causing great irritation of the nose and eyes, and in a concentrated state spasms of the muscles of the eyes and lacrymation. Its odour and action are like those of a mixture of mustard and garlic oil. By the same process

Materials.

Products.

Volatile acids.

Volatile alkalies.

Methylated ammonias.

Description of more complicated alkalies.

Fluorescentine.

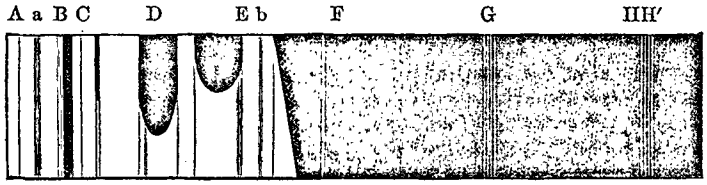
Parafluine.

Irritating substance.

Fluopittine.

another product, fluopittine,* is obtained. Fluopittine, insoluble in dilute sulphuric acid and in ether, is easily soluble in alcohol. The solution

Intensity Diagram of Spectrum of Fluopittine.



has a reddish brown colour, and properly diluted yields a remarkable spectrum. This shows two absorption bands in red which are thin like sun-lines, and two broader bands in green. (See Plate IV. fig. 3.)

1 = β. 3 = α.
2 = δ. 4 = γ.

Possibly it is only the resinous product of the decomposition in overheated alcoholic solution of fluorescentine. It is at present impossible to discuss the significance of any of these substances. But it is remarkable that the extracts of tetanus organs and of the parts from cholera bodies yielded a small quantity of fluorescentine.

I instituted a careful discussion of the phenomena of fluorescence exhibited by the new bodies, and a comparison with the "animal quinoidine" discovered by Drs. Dupré and B. Jones. The latter has a purely sky-blue fluorescence, and is made optically inert by hydrochloric acid, like quinine. It differs, therefore, greatly from fluorescentine.

Importance of fluorescence phenomena.

The phenomena of fluorescence will in future yield important means of diagnosis in animal chemistry. When speaking of urochrome I shall have to describe two of its products, which yield absorption and fluorescence phenomena in the spectrum and condensed sunlight. Possibly fluorescentine may be the chemolytic form of that particular part of the nucleus of albumen, which in the course of biolysis leads to urochrome, and by the chemolysis of the latter to omicholine and omicholic acid.

Thiotherine.

I further extracted from the albumen products a crystallised substance containing sulphur, thiotherine; as the process is at present only small quantities are obtainable, 70 pounds of acid and 50 pounds of hair having yielded me only a few grains.

Fluorescentic acid.

There was also extracted an uncrystallisable acid, fluorescentic acid, which seems to be the basis of all albuminous substances. This was studied in many ways, like all the other new substances, but the technical details of these inquiries have to be excluded from the present account. Of other known matters, tyroine, leucimide, and leucine were extracted.

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* This was found to be very similar to the spectrum of cholonematine, a particular biliary coloured matter (reported, B. II., from Norman), part soluble in ether. This also had the two thin lines, but reversed in order, the thinnest being towards the red end, and two broad bands in green.

1 = δ
2 = α
3 = β
4 = γ

Cut off at blue, even in very dilute solution. See p. 229.

If fluopittine were a derivate from tyroine by the influence of iodine, the similarity of its spectrum with that of the biliary matter would be more easily explained. For tyroine contains only one atom of water more than cholophæine, and might therefore yield similar derivates as the latter.

In order to decide whether thiotherine was not merely a mixture of leucimide with some sulphurous body, I instituted some researches on leucimide. It was produced from leucine by a reaction, which also yielded an oil and amylamine, together with leucine hydrochlorate. Five elementary analysis showed it to be $\mathfrak{C}_6\,H_{11}\,N\mathfrak{O}$. Consequently it contained an atom of water less than leucine. It could not have any relation to thiotherine, which contained 19·9 per cent. of sulphur. Of tyroine* many reactions were studied. The product of its action upon mercurous nitrite, which is dark red, was subjected to spectral analysis. It showed no special absorptions. Erythrosic acid from tyroine by nitrous acid was found to be an acid, and its insoluble barium-salt was obtained and partially analysed. The product of the destructive distillation of tyroine hydrochlorate was found to have great fluorescence, to crystallise and dissolve in alcohol. On leucine many researches were instituted which yielded most interesting and useful results. A new mode of purifying it yielded technical facilities, which were used in the production of a considerable amount of pure leucine, to be used in future experimental pathological inquiries, particularly those relating to rheumatic fever and endocarditis by acids of the lactic acid series. Leucine ($\mathfrak{C}_6H_{13}N\mathfrak{O}_2$) is an amido-acid. It occurs in so many parts of the body under such a variety of circumstances, that some methods for its better and more complete isolation were highly desirable. I therefore studied its compounds, and found that the copper compound seemed to offer facilities for that purpose. In studying this compound I obtained several new combinations with that metal, which I will shortly characterise.

Leucimide. Tyroine. Leucine.

Dicupric trileucine, $\mathfrak{C}_{18}H_{35}\mathfrak{C}u_2N_3\mathfrak{O}_6$ with 24·58 per cent. $\mathfrak{C}u$ required, and 24·47 found; 8·1 per cent. N required and 8·3 per cent. found. Monocupric dileucine, $\mathfrak{C}_{12}H_{26}\mathfrak{C}uN_2\mathfrak{O}_5$ with 18·55 per cent. $\mathfrak{C}u$ found, 18·56 required. Both these salts were obtained by various proceedings; one exhibited the power of leucine to displace hydrochloric acid. To leucine hydrochlorate oxyde of copper was added to saturation; the solution was evaporated. Ultimately all leucine was combined with copper, all acid was volatilized. Monocupric trileucine $\mathfrak{C}_{18}H_{37}\mathfrak{C}uN_3\mathfrak{O}_6$, 13·95 $\mathfrak{C}u$ required, 14·38 per cent. found, was obtained by boiling with water monocupric dileucine. Under these circumstances the neutral salt breaks up as follows:—

Copper-compounds of leucine.

$$\underbrace{\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ \\ \end{matrix}\right\}\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ \mathfrak{C}u\end{matrix}\right\}\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ \mathfrak{C}u\end{matrix}\right\}}_{\text{3 atoms monocupric dileucine.}} = \underbrace{\left\{\begin{matrix}\tilde{L}\,\tilde{L}\,\tilde{L}\\ \mathfrak{C}u\end{matrix}\right\}}_{\text{1 atom monocupric trileucine.}} + \underbrace{\left\{\begin{matrix}\tilde{L}\,\tilde{L}\,\tilde{L}\\ \mathfrak{C}u\mathfrak{C}u\end{matrix}\right\}}_{\text{1 atom dicupric trileucine.}}$$

$\mathfrak{C}u = 18·56$ per cent. $\mathfrak{C}u = 13·95$ per cent., $\mathfrak{C}u = 24·58$ per cent.

The mercury compounds were very variable, one quite insoluble in cold and boiling water was found to be pentamercuric hexaleucine $\mathfrak{C}_{36}H_{69}\mathfrak{H}g_5N_6\mathfrak{O}_{12}$; $\mathfrak{H}g$ required 57·94 per cent., found 57·09 per cent.

* Formerly termed tyrosine, but the terminal "s" of tyros not belonging to the root, has for grammatical reasons no place in the compound.

Historical references.

VI.—COLOURING MATTERS OF THE BILE.

What is now comprehended in the chemistry of bile begins with its chemolysis by Leopold Gmelin, which evolved as products cholic acid and taurine. The same accomplished chemist and philosopher isolated glycocholic acid, so that the discovery of Platner's crystallised bile left only glycocoll to be discovered, and the connection of the various products to be established. This was done to perfection by Strecker, who also added choline to the list of biliary ingredients. Pathological researches evolved the presence of cholesterine. But the chemical description was incomplete as long as the coloured ingredients remained in an undefined condition. A great research was therefore undertaken by me in the Pathological Laboratory. The analytical proofs will have to be published elsewhere. But in the following I give a full abstract of the research, with the omission only of the technical analytical details.

Historical Retrospect.—The colouring matter of bile has repeatedly attracted the attention of chemists and physicians. The first attempt to extract it from bile was made by Berzelius. He obtained a yellow substance which was soluble in ether, and contained soda, and was named bilifulvine. He also endeavoured to extract the green colouring matter, by combining it with baryta. When the green precipitate was decomposed with hydrochloric acid, biliverdine was left. At a later period, Scherer attempted (Ann. Chem. und Pharm. 53, 377) to isolate the yellow colouring matter of bile contained in the urine of jaundiced persons, and performed the elementary analysis of a substance obtained from such urine, as also the analysis of a colouring matter which by a different proceeding had been obtained from gallstones. The colouring matter from gallstones was also subjected to elementary analysis by Hein and Marchand (Physiol. Chem. 25). As the substance analysed by these chemists was yet very impure it yielded no satisfactory results. Some addition to our knowledge regarding the nature of this substance was made by the researches of Heintz (Poggendorf, Annal. 84, 106). He purified the colouring matter from gallstones by solution in carbonate of soda, and separated by means of alcohol the brown from the green modification. He further investigated the metamorphosis of the brown into the green colouring matter under the influence of alkalies and air, and upon the basis of several elementary analyses he conceived this metamorphosis to consist in an oxydation. One equivalent of biliphæine absorbed, according to the theory of Heintz, one equivalent of oxygen, and then split up into two equivalents of biliverdine ($C_{32} H_{18} N_2 O_9 + O = 2 (C_{16} H_9 NO_5)$. After Valentiner (Günsburg's Zeitschrift N. F. 1, 46, 1859) had extracted a crystallised matter from gallstones by means of chloroform, which matter he announced to be hematoidine, Städeler (Frerichs, Klin. d. Leberkr.) applied the same solvent upon gallstones and obtained crystallised biliphæine, to which, in accordance with his analysis, he attributed the formula $C_{18} H_9 NO_4$. At a later period, however, Städeler published (Mittheilungen aus dem chem. Laborator. in Zürich, 1864) a more extensive paper on the colouring matters in human gallstones, in which, based upon new elementary analysis and one atomic weight determination, he attributed the formula of $C_{32} H_{18} N_2 O_6$ to the red colouring matter of bile, and termed it bilirubine. He observed its transformation into biliverdine, as described by Heintz, and formularized the process, without having performed any additional

analysis, thus, that one equivalent of bilirubine by the absorption of two equivalents of water and two equivalents of oxygen passed into biliverdine, to which latter he attributed the hypothetical formula $C_{32} H_{20} N_2 O_{10}$. He further distinguished bilifuscine, which was obtained directly from gallstones, and not produced from bilirubine, but placed into a relation to this substance. Its empirical formula was given as $C_{32} H_{20} N_2 O_8$, thus being distinguished from bilirubine by exceeding its formula to the amount of 2 HO. But by solution in alkali it yielded no biliverdine. Städeler further distinguished biliprasine, which was also extracted ready formed, not produced artificially, and on analysis yielded figures from which it was possible to calculate the formula $C_{32} H_{22} N_2 O_{12}$, distinguished from the hypothetical biliverdine by an excess of 2 HO, and a colour test of its spirituous solution with caustic ammonia. Biliprasine was not obtained from biliverdine; no processes were indicated by which both substances could be separated. Already, in the year 1861, I communicated to the British Association for the Advancement of Science some researches on the metamorphosis of the colouring matter of bile by oxygen and nitrous acid, which afterwards were embodied with my work on gallstones (London, Churchill, 1862). Subsequently I performed numerous analyses of the red colouring matter of bile, and studied its transformation into the green modification. In a paper by Maly (Ann. Chem., 1864) it has since been asserted, as I shall show erroneously, that the change of the red modification into the green was accompanied with the elimination of amide.

The experiments of Städeler were performed, as is stated, upon human gallstones exclusively. From the description which he gives of one of his most useful calculi, there is a possibility of its having been a concretion from a cow.

Maly's experiments were made upon colouring matter which had been extracted from the bile of several persons who had died of the most varied diseases. My own experiments were mostly instituted upon the colouring matter obtained from ox gallstones. But I also examined a considerable number of human gallstones, and proved the identity of the colouring matter contained in them with that constituting the bulk of the animal concretions.

Mode of obtaining a Red Colouring Matter from Ox Gallstones.—The ox gallstones are powdered and sifted through cambric. Much dust is produced during this operation, and covers the operator with a pertinaciously adhering yellow colour. It is necessary to exclude the dust from the air passages by cloths wrapped round face and neck, as it easily causes a furred tongue and fever when inhaled and swallowed. The powder is next stirred up with hot water in the same manner in which cooks are in the habit of mixing dough, to prevent the formation of lumps of dry dust. When every portion is well moistened a large quantity of hot water is added while the mixture is well stirred; it is then allowed to stand at rest for several days. The fluid is then separated from the deposit by decantation. If the operator is not desirous of examining the water extract of ox gallstones it is not worth while to filter this fluid, which remains turbid on account of a small quantity of suspended colouring matter. The powder is washed by the repeated addition and subsequent decantation of water, until at last it is placed upon a filter and washed pure by percolation. The paste is then transferred into a flask, a large quantity of strong alcohol added, and the mixture is digested and boiled in a water-bath. The alcohol extracts a free biliary acid, a lime salt of an organic fatty acid, and, rarely, a little

cholesterine. The powder is exhausted with alcohol, lastly, on the filter placed in a hot funnel, until the alcohol is only faintly yellow, and on evaporation leaves only a little colouring but no resinous matter. The exhausted powder is now treated with cold dilute hydrochloric acid, which causes the evolution of carbonic acid and sulphuretted hydrogen. It is better to allow the acid to act upon the powder for some days at the ordinary temperature, than to increase its dissolving power in time by the employment of heat. The powder is washed by decantation, lastly, on the filter, and treated a second time with alcohol. It now extracts but little biliary acid, but a brown colouring matter, which has evidently been set free by the acid (mainly bilirubine), which is slightly soluble in alcohol. After complete exhaustion with alcohol the residue may yet be treated with ether, but if the former operations have been completely performed this agent will extract little or nothing besides a little bilirubine.

Treatment with hydrochloric acid.

Second treatment with alcohol.

Extraction with ether.

Drying.

After drying the powder is of a fine reddish yellow colour, which speedily becomes red or brownish red when exposed to the light. It is now boiled with pure chloroform, free from water and hydrochloric acid, care being taken to condense and cause to flow back into the flask the evaporated chloroform. The chloroform solution may now be filtered off, and the residue from the filter returned into the flask, to be anew boiled with chloroform. Large quantities of chloroform are of necessity lost during this operation. The powder may also be placed into a so-called exhauster, but then the advantage of being able to boil the chloroform with the powder is lost.

Boiling with chloroform.

Modus operandi.

The following mode of operating is the most advantageous:—The solution obtained by boiling is allowed to stand at rest with the powder in the closed flask for 24 hours. After that time all powder has collected on the top of the fluid; the clear dark red solution fills the bottom of the flask. This solution is now drawn off by means of a syphon fixed in a cork, which closes a second flask, and which is partly emptied of air by suction with the mouth through a second tube piercing the cork, after the free end of the syphon has been immersed to the bottom of the flask containing the powder and solution. The fluid thus drawn off is obtained perfectly clear by filtration through paper. From the red solution most of the chloroform is distilled off in the water-bath. The residue is placed on a filter, washed with chloroform, then with absolute alcohol until the latter is nearly colourless, and the residue on the filter purely red, without any admixture of green. The colouring matter thus obtained is magnificently red, and of exactly the same appearance as the red oxyde of mercury obtained by heating the nitrate. Absolute alcohol and ether extract from it no heterogeneous substance, and only little of the colouring matter itself. But it is well to purify it once more by solution in chloroform, and precipitation of the concentrated solution by absolute alcohol.

Purification.

After the chloroform has repeatedly acted upon the gallstone powder the amount of colouring matter extracted by each operation becomes exceedingly small. It is then advisable to treat the dried powder again with dilute hydrochloric acid, to wash it with water and spirit, and after drying to resume extraction with chloroform; or the dried powder may be treated with an alcoholic solution of caustic potash. The colouring matter dissolves with a dark reddish brown colour, and can easily be separated from the sediment of impurities by filtration. The filtrate after acidulation with hydrochloric acid deposits the red colouring matter in flakes, which are quickly collected on a filter, and then boiled in absolute alcohol or shaken with chloroform. After cooling the precipitate is collected on a filter, and washed with absolute alcohol. It

Repeated extraction with H Cl.

Precipitation.

is a yellowish powder, which owing to its finely subdivided state quickly becomes green on the surface by oxydation. In that case it must be again treated with absolute alcohol. The chloroform washings, which are dark green, should after distillation of some chloroform be precipitated with absolute alcohol, to obtain the rest of bilirubine. From the various mother liquors much green colouring matter may be obtained, particularly from the first alcoholic acid solution, by addition of water.

Biliphæine and bilirubine.

Biliphæine and Bilirubine.—Before the discovery of the use of chloroform as a solvent of the colouring matter, only brown modifications of this substance were known and obtainable by the several processes then in use, particularly that employed by Heintz. These brown matters were termed biliphæine or cholophæine, according to the more or less puristic tendencies of authors. When, however, the red colouring matter was obtained by means of chloroform, it was generally assumed that the brown colour of former preparations had been a sign of impurity. The red colouring matter accordingly went by the name of cholerythrine or bilirubine, and was believed to be the only form of pure colouring matter of bile.

During many operations for the isolation of pure colouring matter of bile I regularly obtained two modifications, one being reddish brown, the other of a purely red colour, like nitric oxyde of mercury. The brownish red products were kept apart for further purification. The purified product showed a darker, somewhat purple brown colour, but in all other respects behaved like the purest bilirubine. On microscopic examination it was found to consist of large crystalline particles, mixed with many perfect crystals. The bilirubine on the other hand consisted almost entirely of minute amorphous granules; only when it had been precipitated by alcohol it showed minute yellow rhombic prisms. When the mixture of chloroform solution and alcohol, from which the first or immediate precipitate of bilirubine had been removed by filtration, was allowed to stand and mixed gradually with some more alcohol, it deposited another quantity of colouring matter partly red, partly brown, the former amorphous, the latter in large crystals united to clusters. The brown crystalline part could be separated by lævigation with alcohol, in which it settled quicker than the red matter.

Crystals of cholophæine.

The crystals thus isolated had a dark reddish brown colour; their surfaces reflected the light with a purple and steel blue glitter. They were opaque under the microscope; thin scales appeared reddish or red; the very thinnest crystals, of which there were few, transmitted the light with a yellow colour. The crystals were mostly from one-tenth to one-eighth of an inch in length, of from one-twentieth to one-thirtieth of an inch in width, and their third diameter was probably from one-hundredth of an inch to immeasurable thinness. By their form they belonged to the rhombic system, being prisms in some crystallisations simple and with obtuse nearly right angles, in others with sharp angles on the one, obtuse angles on the next edge, and planes from secondary prisms cutting off the sharp angles of the primary ones.

The most minute crystals of bilirubine also showed the same shape, and were of a yellow-colour. The red modification could by cautious crystallisation always in part be transformed into the brown. Without special elementary analysis of the two modifications, it may be considered as proved that this colouring matter appears in two modifications, a crystallized or crystalline one of purple brown colour, cholophæine or biliphæine, and an amorphous one of a bright red colour, bilirubine.

This observation will explain the discrepancies concerning this substance which have existed in the writings of many authors. It disproves the statement of Städeler that the pure colouring matter of bile

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was red only, and that when a product of this kind was not red but brown and crystallised it was impure.

In the following I shall consider cholophæine and bilirubine as identical chemical substances: but whenever the one or the other name is used in the description of a process, the reader will understand that the modification indicated by the name has been taken for the experiment.

Influence of light.

The red nearly orange coloured amorphous colouring matter when exposed to light, while all moisture is carefully excluded, gradually assumes a brown colour on its surface. In the interior the powder remains unchanged for a long time. When boiled with water for some time it assumes the same brown colour. In water it is quite insoluble,

Solubility.

slightly soluble in boiling absolute alcohol, with a yellow colour; on filtration through paper the colouring matter of the first portions of alcoholic solution remains adhering to the paper fibres, and the alcohol passes nearly white.

In ether it is very little soluble, somewhat easier in sulphide of carbon and benzole. The best solvent is chloroform, of which 512 parts dissolve about one part of colouring matter. The rays of the sun discolour the chloroform solution; the addition of hydrochloric acid produces a precipitate in it.

Bilirubine when prepared as above and dried in vacuo lost yet some water and then was constant. By many variegated elementary analyses

Composition.

its composition was ascertained to be $\mathfrak{C}_9\ H_9\ N\mathfrak{O}_2$.

Atoms.	Atomic Weights.	In 100.
$9\mathfrak{C}$	108	66·26
9H	9	5·52
N	14	8·59
$2\mathfrak{O}$	32	19·63
	163	100·00

Compounds of Cholophæine.

Neutral silver salt.

Neutral Monohydrated Cholophæinate of Silver. — A neutral solution of cholophæine in ammonia, prepared by digesting a dilute ammonia solution in water with excess of cholophæine, was precipitated with nitrate of silver. The precipitate was of a reddish brown colour, and after washing with water was dried in the vacuum over sulphuric acid, light being completely excluded.

The mean of several determinations gave 37·39 per cent. of silver.

Taking into consideration that the analyses of cholophæine or bilirubine led to the empirical formula $\mathfrak{C}_9\ H_9\ N\mathfrak{O}_2$, there cannot be any doubt but that the quantity of silver found in the cholophæinate is exactly that required by a neutral monohydrated compound of the formula $\mathfrak{C}_9\ H_{10}\ Ag\ N\mathfrak{O}_3$. However anomalous may be a silver salt containing an atom of water, it is now certain that the composition and molecule of cholophæine is expressed by the formula $\mathfrak{C}_9\ H_9\ N\mathfrak{O}_2$.

Theory of cholophæinate of silver dried in vacuo $= \mathfrak{C}_9\ H_{10}\ Ag\ N\mathfrak{O}_3$.

Symbols.	Atomic Weights.	Per Cents.
$\mathfrak{O}_9$	108	37·50
H_{10}	10	3·47
Ag	108	37·50
N	14	4·86
$\mathfrak{C}_3$	48	16·67
	288	100·00

Basic Anhydrous Cholophæinate of Silver. — An ammoniacal solution of cholophæine (which cholophæine had been repeatedly purified by solution in chloroform and in caustic potash and alcohol) was treated with nitrate of silver. No precipitate appearing an excess of silver was added, and then some nitric acid to neutralize as nearly as possible the excess of ammonia. A precipitate now formed, the solution became perfectly colourless, and the precipitate was washed with water. It was dried in vacuo at 130° C.

Basic silver salt.

It is thus shown that cholophæinate of silver is soluble in free ammonia, and that when the ammoniacal solution, in the presence of an excess of silver-solution, is neutralized down to a proper degree, the basic salt falls down. Its theory is derived from the data concerning free cholophæine, the neutral silver-salt, and from direct analysis its formula is $C_9 H_7 Ag_2 NO_2$. In this compound two atoms of hydrogen are replaced by two of silver. An analogous lead compound in which the two atoms of hydrogen are replaced by one didynamic atom of lead will be described lower down. Its formula is $C_9 H_7 Pb NO_2$, and its production strengthens the presumptions in favour of the basic silver compound.

Theory of basic cholophæinate of silver dried in vacuo $= C_9 H_7 Ag_2 NO_2$.

Symbols.	Atomic Weights.	Per Cents.
C_9	108	28·64
H_7	7	1·85
Ag_2	216	57·29
N	14	
O_2	32	
	377	

Neutral barium salt.

Neutral Cholophæinate of Barium.—An ammoniacal solution of cholophæine with excess of ammonia was precipitated by chloride of barium. The dark greenish brown precipitate was washed until the filtrates were free from barium; the filtrates were all somewhat green coloured, and on standing deposited green flakes. The compound was dried at 100°, and formed a dark brown powder.

The analyses yielded data corresponding to the requirements of a barium compound, which is strictly analogous to the neutral silver-salt, containing a didynamic atom of barium, which solders together two molecules of cholophæine by replacing one atom of hydrogen in each of them; two molecules of water are superadded.

Theory of barium cholophæinate $= C_{18} H_{20} Ba N_2 O_6$.

Symbols.	Atomic Weights.	Per Cents.
C_{18}	216	43·46
H_{20}	20	4·02
Ba	137	27·56
N_2	28	,,
O_6	96	,,
	497	

Half-acid barium salt.

Half-acid Cholophæinate or Sesqui-cholophæinate of Barium.— This salt, prepared by precipitation from a neutral ammoniacal solution by $Ba Cl_2$, washing with water, treating and boiling with alcohol until the alcohol on filtration and washing passed clear and colourless, was dried

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in the steam closet. It remained of a brownish red colour, but after being powdered it became of a darker brown colour on the surface during drying. Dried at 100° until constant, and then at 110° C., it yielded on analysis data which showed that in this cholophæinate one atom of barium is in combination with three molecules of cholophæine. If to the dihydrated neutral cholophæinate of barium described above we add one molecule of cholophæine, thus—

1 cholophæinate of barium $\mathfrak{C}_{18} H_{20} \mathfrak{B}a N_2 \mathfrak{O}_6 = 497$ At. W.

1 cholophæine $\mathfrak{C}_9 H_9 N \mathfrak{O}_2 = 163$ „

We obtain - - $\mathfrak{C}_{27} H_{29} \mathfrak{B}a N_3 \mathfrak{O}_8 = 660$ „

To the theory of this compound the above analyses exactly correspond, as is evident from the following comparison :—

Symbols.	Atomic Weights.	Per Cents.	Found Mean.
$\mathfrak{C}_{27}$	324	49·09	50·63
H_{29}	29	4·39	4·37
$\mathfrak{B}a$	137	20·75	20·66
N_3	42		
$\mathfrak{O}_8$	128		
	660		

By the following comparison the differences in the composition of the neutral and the half-acid cholophæinate of barium will be exhibited in a striking manner.

NEUTRAL CHOLOPHÆINATE OF BARIUM. $\mathfrak{C}_{18}H_{20}\mathfrak{B}aN_2\mathfrak{O}_6$ Atom W. = 497.		HALF-ACID CHOLOPHÆINATE OF BARIUM. $\mathfrak{C}_{27}H_{29}\mathfrak{B}aN_3\mathfrak{O}_8$ Atom W. = 660	
Theory	Found.	Theory.	Found.
$\mathfrak{C}$ 43·46	44·58	$\mathfrak{C}$ 49·09	50·63
H 4·02	3·98	H 4·39	4·37
$\mathfrak{B}a$ 27·56	27·55	$\mathfrak{B}a$ 20·75	20·66

Neutral calcium salt.

Neutral Cholophæinate of Calcium.—The excess of cholophæine, which had served to make the neutral-ammoniacal solution used for the production of cholophæinate of silver, was dissolved in a slight excess of ammonia and precipitated by chloride of calcium. The precipitate was red. Dried at 100° it yielded on analysis data which are given at length in the paper. Calculating from these data a formula, we obtain a neutral cholophæinate of calcium $\mathfrak{C}_{18} H_{20} \mathfrak{C}a N_2 \mathfrak{O}_6$, which is in every respect analogous to the neutral barium compound above described. We must assume in it the existence of two molecules of water, which are not expelled even at the temperature of 100°. The following comparison of theory with the analytical data will make the correctness of these conclusions more conspicuous :—

Symbols.	Atomic Weights.	Per cents.	Found Mean.
$\mathfrak{C}_{18}$	216	54·00	53·86
H_{20}	20	5·	4·90
$\mathfrak{C}a$	40	10·	10·17
N_2	28		
$\mathfrak{O}$	96		
	400		

Half-acid Cholophæinate or Sesqui-cholophæinate of Calcium.—I had first of all cholophæinates prepared the barium salt, which was found to be a sesqui salt. The neutral calcium salt was next obtained, and indicated the existence of two classes of salts, neutral and half-acid. The correctness of this conclusion was put to the test by the endeavour to obtain the neutral barium salt, and the experiment proved successful. It was next necessary to obtain the half-acid cholophæinate of calcium. A neutral solution of bilirubine was therefore precipitated by chloride of calcium washed and dried.

Half-acid calcium salt.

The compound was found to be analogous to the half-acid barium compound already described, and has the formula $\mathfrak{C}_{27}H_{29}\mathfrak{C}aN_3\mathfrak{O}_8$, and the following theory :—

	Theory of atoms.	Theory of per cents.
$\mathfrak{C}_{27}$	324	57·54
H_{29}	29	5·15
$\mathfrak{C}a$	40	7·1
N_3	42	
$\mathfrak{O}_8$	128	
	563	

The following comparison exhibits the differences in the composition of the neutral and the half-acid cholophæinate of calcium.

Neutral Cholophæinate of Calcium. $\mathfrak{C}_{18}H_{20}\mathfrak{C}aN_2\mathfrak{O}_6$ At. W. = 400.		Half-acid Cholophæinate of Calcium. $\mathfrak{C}_{27}H_{29}\mathfrak{C}aN\mathfrak{O}_8$ At. W. = 563.	
Theory.	Found.	Theory.	Found.
$\mathfrak{C}$ 54·	53·86	$\mathfrak{C}$ 57·54	60·37
H 5·	4·9	H 5·15	5·74
$\mathfrak{C}a$ 10·	10·17	$\mathfrak{C}a$ 7·1	6·91

Explanation of Städeler's error.

In his researches on the colouring matter of human gallstones, Städeler produced a combination of bilirubine with calcium, which on analysis yielded him 9·1 per cent. of calcium oxyde. Assuming this compound to be the normal neutral salt, he allowed the atomic weight of bilirubine to be thereby determined, and rejecting his former analyses of crystallized cholophæine as given in Frerich's Treatise on Diseases of the Liver, he abandoned the empirical formula $C_{18}H_9NO_4$, and substituted $C_{32}H_{18}N_2O_6$ as the formula of the bilirubine, and $C_{32}H_{17}CaN_2O_6$ as that of bilirubate of calcium. (The foregoing three formulæ are given in the old notation.) As this formula is supported by only one, and that a very unsatisfactory calcium determination, and as all the analyses of Städeler concerning bilirubine or cholophæine can be brought into harmony with my results, I can have no hesitation in considering his formulæ, both of bilirubine and bilirubate of calcium, as erroneous. The bilirubate analysed by Städeler was evidently the sesquisalt.

Theory of $\mathfrak{C}_{27}H_{29}\mathfrak{C}aN_2\mathfrak{O}_6$ requires		Städeler found	
$\mathfrak{C}a\mathfrak{O}$	or $\mathfrak{C}a$	$\mathfrak{C}a\mathfrak{O}$	or $\mathfrak{C}a$
9·94 per cent.	7·1 per cent.	9·1 per cent.	6·5 per cent.

With Städeler's formula of bilirubine fall the formulæ of all other substances described by him under the names of biliverdine, biliprasine, bilifuscine, and bilihumine.

It remains to point out in this place the circumstances under which cholophæine will form half-acid, neutral, or basic salts. A watery solution of ammonia which is saturated with cholophæine by digestion with an insoluble excess yields on the addition of neutral salts of metals the sesquisalt. Possibly the ammonia salt is itself a sesquisalt while dissolved in water. From somewhat alkaline solutions the basic salts of silver and lead are precipitated by the opportune addition of an excess of metallic salt. But neutral salts of earths added to solutions containing excess of ammonia precipitate the neutral compounds with earths.

Zinc salt.

Cholophæinate of Zinc.—A neutral ammoniacal solution of cholophæine was precipitated with sulphate of zinc. The reddish brown precipitate was easily washed, and quite insoluble in water. Dried at 100° C. it was subjected to analysis. From the amount of zinc found it is evident that this compound is constructed upon the plan of the half-acid salts of calcium and barium. Thus—

1 neutral cholophæinate of zinc	$C_{18}H_{16}ZnN$	O_4
2 water - - -	H_4	O_2
1 cholophæine - -	C_9H_9	NO_2
1 molecule half-acid cholophæinate of zinc -	$C_{27}H_{29}ZnN_3O_8$	

Theory of $C_{27}H_{29}ZnN_3O_8$

Atoms.	Sums of Atomic Weights.	Per cents.
C_{27}	324	"
H_{29}	29	"
Zn	65	11·05
N_3	42	
O_8	128	
	588	

Neutral lead salt.

Neutral Cholophæinate of Lead.—Precipitated from a neutral solution by acetate of lead. Dried at 100°. Figures were obtained which keep in proximity of those required by a neutral dihydrated cholophæinate $C_{18}H_{20}PbN_2O_6$. At. W. = 567, Pb = 36·50 per cent.

The half-acid cholophæinate of lead $C_{27}H_{29}PbN_3O_8$ = 730 requires 28·21 per cent. of Pb.

Basic lead salt.

Basic Cholophæinate of Lead.—The compound was precipitated by acetate of lead in great excess from a neutral ammoniacal solution of cholophæine (rubine), which, although it did not dissolve any more cholophæine, smelled of ammonia, and had an alkaline reaction. Dried at 100° C.

This compound may be explained as being a basic cholophæinate, or cholophæine, in which two atoms of hydrogen are replaced by one didynamic atom of lead.

Atoms.	At. Weights.	Per cents.	Found Mean.
C_9	108	"	"
H_7	7	"	"
Pb	207	56·25	58·1
N	14		
O_2	32		
	368		

This compound corresponds to the basic-cholophæinate of silver, or binargentic cholophæine, described above, $C_9H_7Ag_2NO_2$.

Neutral Cholophæinate of Copper.—This salt was precipitated by sulphate of copper from a neutral solution.

Basic Cholophæinate of Copper.—This salt was obtained by precipitating an ammoniacal solution with excess of acetate of copper.

The only probable formula for this compound is that of a cholophæinate containing 2 cholophæine and 3 copper.

Atoms.	Atomic Weights.	Per Cents.	Found.
C_{18}	216	"	"
H_{12}	12	"	"
Cu_3	190·5	37·31	38·70
N_2	28		
O_4	64		
	510·5		

Neutral copper salt.

Basic copper salt.

On Cholochlorine, or Biliverdine.

When bilirubine is dissolved in caustic potash and exposed to the air it becomes gradually green. This change can be accelerated by warming the solution and passing a current of air through it. When in thin layers it is purely green, without any admixture of red or yellow, the reaction is complete. On addition of hydrochloric acid a green matter is precipitated in flakes, which is first washed by decantation, and lastly edulcorated on the filter. This is biliverdine.

Mode of producing biliverdine.

Chemical Properties.—Biliverdine is easily soluble in alcohol, with a splendid green colour, particularly while in the wet state; after drying it is soluble with great difficulty only; it is more soluble in hot than in cold alcohol. It is soluble in hydrochloric acid, forming a green solution, in which platinum-tetrachloride and mercury dichloride produce amorphous green precipitates. A quantity of alcoholic solution boiled down with tincture of iodine, and the residue shaken with dilute caustic potash, left a greenish-black resin, which was not soluble in sulphuric acid except under evolution of sulphurous acid, indicating decomposition. By reducing agents the biliverdine cannot be retransformed into cholophæine. Dissolved in caustic potash and treated with hydrothion it assumes a greenish-brown colour, but the original red is not produced. When metallic zinc is added to a solution of biliverdine in hydrochloric acid, the green colour disappears and gives way to a brownish-red one, but the produce is insoluble in chloroform. An alkaline solution treated with sodium-amalgam changes its colour to a reddish brown, and a small quantity of a brown matter is deposited in flakes. But the reddish-brown matter on exposure to air does not become green again. Hydrochloric acid precipitates a brown flaky matter from the alkaline solution.

Chemical properties.

Soluble in alcohol in HCl.

Reducing agents.

When chlorine gas is passed into water containing biliverdine in suspension, dark yellow flakes are obtained, which while insoluble in water and ether dissolve easily in alcohol. When a few bubbles of chlorine gas are conducted into an alcoholic solution of biliverdine the dark-green fluid is instantaneously discoloured. After evaporation of the alcohol yellowish white flakes remain, which by a gentle heat fuse to a reddish yellow mass. They contain chlorine, and are a mixture of at least three compounds, which can be separated by chloroform.

Effect of chlorine.

Biliverdine when repeatedly purified and subjected to variegated analyses gave data which led to the formula $C_8H_9NO_2$.

Composition.

	Theory of atoms.	Theory in 100.	Mean found.
8 C	96	63·57	62·94
9 H	9	5·96	6·13
N	14	9·27	9·34
2 O	32	21·20	22·10
	151	100·00	100·00

This shows that biliverdine arises from bilirubine by the addition of 2 oxygen, and the subsequent subtraction of 1 carbonic acid.

Bilirubine.		Oxygen.		Biliverdine.		Carbonic Acid.
$C_9H_9NO_2$	+	$2O$	=	$C_8H_9NO_2$	+	CO_2.

New test for biliverdine.

On boiling an alcoholic solution of biliverdine with caustic ammonia and nitrate of silver, a reduction of the dissolved silver oxyde is observed. The solution remains green, but on addition of an acid, such as nitric, hydrochloric, or sulphuric, assumes a splendid purple colour. The new body produced is a product of oxydation and termed bilipurpine.

Bilipurpine.

Various reactions.

The alcoholic solution of biliverdine is not altered by boiling with red oxyde of mercury. Lead peroxyde immediately changes its colour to brown, and precipitates a portion of the dissolved matter. The same change of colour without any accompanying precipitation is produced by peroxyde in the presence of ammonia. Peroxyde of lead and sulphuric acid changes the colour of the alcoholic solution to a light yellow, and evolves aldehyde and acetic ether from the alcohol.

Compounds of biliverdine.

Biliverdine dissolves easily in caustic alkalies, and is not precipitated from their solution by any metallic salt. A saturated solution in alcohol gives a precipitate with baryta water. When this reagent is added until a sample filtrate is only pale green, and boiled, all biliverdine is in combination. It must be filtered quickly, air being excluded, and washed with strong alcohol. It cannot be washed with water as the purer it becomes the more soluble it is, and if washing with water were indefinitely continued it would be dissolved entirely. The analyses of this salt led to the conclusion that it contains three molecules of biliverdine and one didynamic atom of barium, and has the formula $C_{24}H_{27}BaN_3O_7$, or $C_{24}H_{27}BaN_3O_6+H_2O$. This is half-acid biliverdate with one atom of water, according to the following theory:—

1 mol. neutral biliverdate	$C_{16}H_{16}BaN_2O_4$	= 437
1 mol. biliverdine	$C_8H_9N\ O_2$	= 151
1 mol. water	$H_2\ O$	= 18

1 mol. of half-acid biliverdate, $C_{24}H_{27}BaN_3O_7$ = 606

Atoms.	At. Weights.	Per Cents.	Mean found.
24 C	288	47·52	48·79
27 H	27	4·45	4·38
Ba	137	22·60	22·41
3 N	42		
7 O	112		
	606		

If the one atom of water be omitted from the calculation, the theory of carbon corresponds better with the experience, but that of the barium less well.

Atoms.	At. Weights.	Theory of per Cents.	Mean found.
C_{24}	288	48·97	48·79
H_{25}	25	4·25	4·38
Ba	137	23·29	22·41
N_3	42	7·14	
O_6	96		
	588		

Compounds with metals.

Lime water yields a precipitate in an alcoholic solution of biliverdine, which does, however, not appear to be a compound in atomic proportions but a mixture of such a one with excess of free biliverdine.

Lead acetate produces a precipitate in the alcoholic solution of biliverdine, which is more soluble in hot than cold alcohol. Basic lead acetate produces a voluminous precipitate, which is so complete that the fluid has the merest green tinge. Acetate of mercury also produces a precipitate more soluble in hot than cold alcohol. Acetate of copper produces a brownish green precipitate, and the filtrate is nearly colourless. The precipitates of lead, mercury, and copper can be washed with water without dissolving. Freshly precipitated silver-oxyde does not combine with biliverdine without change, but produces oxydation. The derivate is yellow, and soluble in water and alcohol.

In an experiment instituted to measure the quantity of oxygen necessary for the transformation of a given quantity of bilirubine into biliverdine, by means of the deoxydation of an alkaline copper solution, several copper compounds were produced, of which two contained the copper in such a form that it could not be removed by carbonated soda, but followed the product into the alcoholic solution. One of these products had a peculiar spectrum, and exhibited an absorption band in blue when viewed by the aid of Drummond's light.

Spectral Phenomena of some of the Colouring Matters of diseased Bile, and of certain artificial Products.

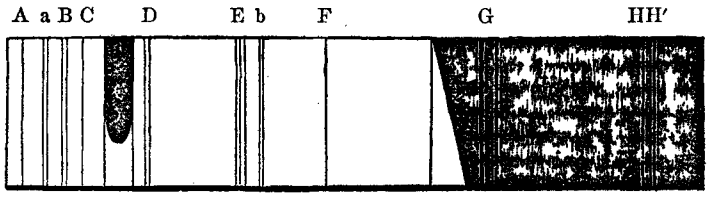
Spectral phenomena of coloured biliary matters.

The normal colouring matters of bile do not yield any particular phenomena of absorption. The spectrum of biliverdine shows red very brilliant and green very prominent, as if the one half of the spectrum was overcast green, the other red. Up to the time of my researches on cholera no derivates of these matters yielding particular *i.e.* characteristic spectra were known. In the report of these researches, p. 496, I gave the first spectra of derivates ever met with. I state again their main phenomena in this place in order the better to be able to appreciate their differences from the newly discovered spectra of pathological colouring matters to be described immediately afterwards.

Cholocyanine.

Cholocyanine.—An ammoniacal solution of cholophæine was treated with concentrated nitric acid until a blue precipitate was formed. This was quickly isolated by filtration, and after washing with water dissolved in alcohol. It showed an absorption band in yellow, which at medium intensity measured 142° 6′—141° 48′=0° 18′. The red was shortened, the green was somewhat obscured; the first half of the blue was clear, but the second half and the rest of the spectrum entirely obscured. See Plate II. fig. 7.

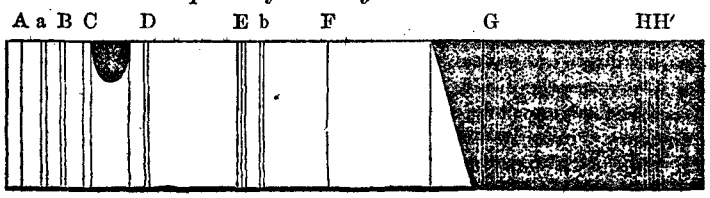
Intensity Diagram of Cholocyanine.



Sulphate of Cholocyanine.

A sulphate of cholocyanine could also be obtained by the action of fuming sulphuric acid and subsequently water upon cholophæine, together with various other green products insoluble in water. The very dilute watery solution showed spectrum, band from 142° 12′ to 141° 48′, very feeble; yellow obscured, red dimmed, green lively, blue only one half its ordinary length, rest obscured.

Sulphate of Cholocyanine dissolved in water.

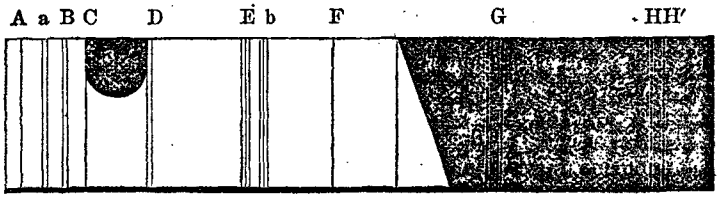


This spectrum of sulphate of cholocyanine by sulphuric acid differs from the one by nitric acid only in this, that the terminal of the band on the red side is 0° 6′ more advanced towards red than that of cholocyanine by nitric acid, while the line nearest to yellow remains the same in both preparations. This spectrum is represented in fig. 8 of Plate II.

Sulphate of sulpho-cholocyanine.

Sulphate of Sulpho-cholocyanine.—Cholophæine was treated with 15 times its weight of sulphuric acid hydrate. After standing six hours it had assumed a reddish green black colour. Diluted with sulphuric acid it was almost impenetrable to light. More diluted red, then a dark band, then some light, but no green, blue, or violet was seen. More diluted there appeared (see fig. 9, Plate II.) red, then band

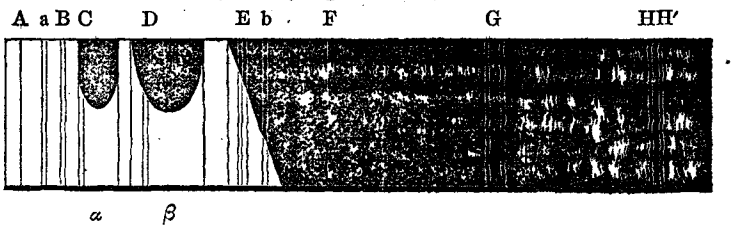
Intensity Diagram of Sulphate of Sulpho-Cholocyanine.



142° 18′—141° 36—0° 42′, green and blue. This band in the concentrated acid solution is broader in both directions than the band of sulphate of cholocyanine in dilute watery solution prepared by fuming sulphuric acid. The line 141° 36′ was difficult to read, and therefore somewhat doubtful. A second reading of dilute solution gave 142° 6′—141° 36′. A third observation of the spectrum of the concentrated solution between two glass plates, so that a very thin layer only had to be traversed by the light, gave 142° 18′—141° 24′, blue and violet being cut off.

Cholothalline.—The concentrated solution just described on dilution with much water deposits a green precipitate, of which a portion is insoluble, another soluble in acohol. The insoluble portion, cholothalline, has the composition $C_9 H_{11} N O_3$, and is therefore hydrated cholophæine, an isomer of tyroine. The soluble portion has in solution a red colour, and shows two remarkable bands of absorption, resembling somewhat to the bands of blood, but being situated in different parts of the spectrum, *i.e.* more towards the red end than those of blood. This spectrum is represented in fig. 10, Plate II. Cholothalline.

Intensity Diagram of Spectrum of soluble Cholothalline.



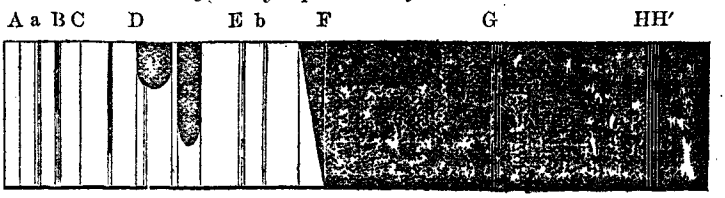
Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 18′—141° 54′ =	0° 24′	3 =	α
2.	141° 48′—141° 6′ =	0° 42′	3 =	β

The green ends in faintest bluish black, and the spectrum altogether at 140° 54′.

The foregoing bodies were artificial derivates of cholophæine by chemical processes. The following substances, however, are natural products of diseased processes.

Cholonematine.—The residue (B. II.) from alcoholic extract of colouring matter from human gallstones was dissolved in ether. The solution appeared green in reflected light, brown in transparent dilute solution. The latter showed a remarkable spectrum of four bands. Of these two were thread-like (hence the name), thin, like sunlines; two broader ones were in green and blue. (See Plate IV. fig. 4.) Cholonematine.

Diagram of Spectrum of Cholonematine.



Band.	Measurement.	Width.	Intensity.	Rank.
1	on 35		5	= δ
2	„ 51		8	= α
3	„ 59 to 68 =	9	3	= β
4	„ 70 to 77 =	7	7	= γ

Green shaded from 87; cut off at 106. The fine lines are clearly visible with the sulphide of carbon prism only, but are fused together when seen in the magnifying spectroscope with flint-glass prisms. In the latter red extends apparently uniformly to 51, or α, and is there suddenly cut off. Blue is cut off entirely, even in very dilute solution. The four bands

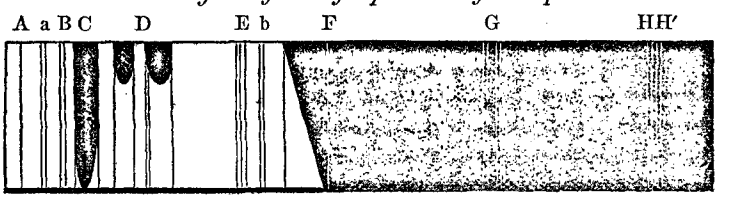
remain to the end, 1 becoming feeblest is therefore δ. Addition of sulphuric acid makes δ and α very feeble. The spectrum has some similarity to that of xanthophyll (from chlorophyll of grass). But the band in red of xanthophyll is one, and certainly α, while the two bands in green are very feeble. The alcoholic solution of ether extract of bilifuscine from human gallstones before precipitation with ether, on comparison showed no bands. Most similar to cholonematine is the spectrum of fluopittine, described in another part of this report. But in this latter the wider of the two thread-like lines, α, is situated towards the red end, and the thinnest one inside of it, the reverse being the case in cholonematine.

Green colouring matter from ox gallstones. Boviprasine.

Boviprasine, a green colouring Matter from Gallstones of Ox.—The alcoholic extraction of the gallstones left on evaporation a resinous residue which dissolved in ether was submitted to spectral analysis. It showed three bands.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	142° 24′ — 142° 6′ =	0° 18′	10	α
2 in yellow	142° — 141° 48′ =	0° 12′	3	β
3 in green	141° 42′ — 141° 24′ =	0° 18′	3	γ

Intensity Diagram of Spectrum of Boviprasine.



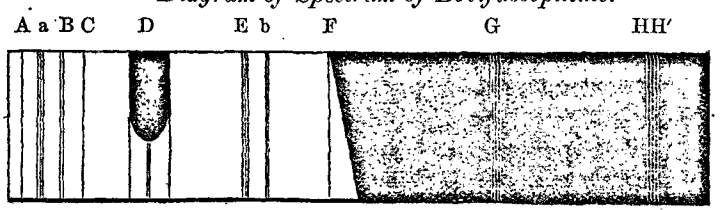
Green cut off at 140° 18′. Seen in the non-magnifying spectroscope, β is divided, a phenomenon not caused by the interference of the sodium line, as this latter is on the green side of the band β.

Compare with boviprasine the spectrum of cellular algæ from pond in Surrey Gardens.

Bovifuscopittine.

Bovifuscopittine.—This resin was extracted from ox gallstones by alcohol. It was treated with caustic potash, precipitated by hydrochloric acid, and dissolved in ether. It did not crystallise. Fatty acids were then removed by precipitation with lime, and the resin was dissolved in alcohol. The solution was brownish yellow to red, without any green tinge whatsoever. In the spectrum it presented a single band overlying the D line. (See Plate IV. fig. 5.)

Diagram of Spectrum of Bovifuscopittine.

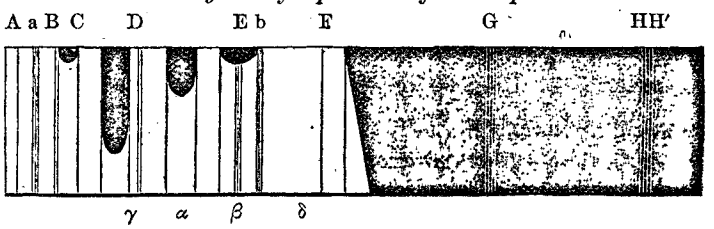


α = 55 to 67 width=12. Intens. 6.

Cut off at 115.

Muscoprasine.—This resin is extracted from ox gallstones by means of alcohol. It has a green colour in the solid state, and retains it on solution in alcohol. In the spectrum it shows bands of great beauty, one in red being very black. (See Plate IV. fig. 6.) The resin has a particular musk flavour. Muscoprasine.

Diagram of Spectrum of Muscoprasine.

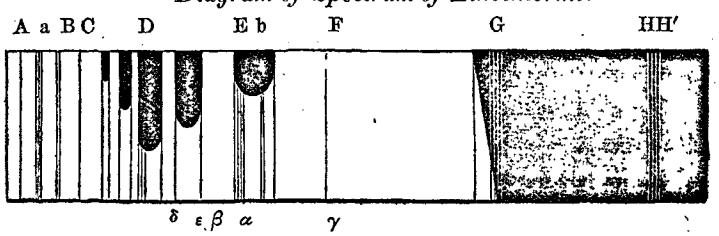


Band.	Measurement.	Width.	Intensity.	Rank.
1.	37 to 42	= 5	1	= γ
2.	50 „ 58	= 8	7	= α
3.	68 „ 77	= 9	3	= β
4.	84 „ 95	= 11	1	= δ

Cut off at 122. 1 and 4 are very feeble bands and difficult to read.

Ethochlorine.—The first ether extraction of ox gallstones yielded a green-coloured substance, which in its second ethereal solution showed the following spectrum (see Plate IV. fig. 7):— Ethochlorine.

Diagram of Spectrum of Ethochlorine.



Band.	Measurement.	Width.	Intensity.	Rank.
1.	48 to 50	= 2	2	δ
2.	54 „ 58	= 4	4	ε
3.	59 „ 66	= 7	7	β
4.	70 „ 77	= 7	5	α
5.	88 „ 100	= 12	3	γ

Violet to 160. In the flint-glass prism and magnifying spectroscope the band 1 is hardly seen. Red reaches to 48, and is then suddenly cut off, but it also reaches to 58, and is then cut off a second time. The margin of the band 1 towards yellow, and that of the band 2 towards the red end, are apparently washed away. This is the most complicated spectrum met with amongst biliary matters, and should be compared to that of cruentine.

Of other coloured ingredients of bile and gallstones, bilifuscine and biliprasine have been chemically examined in various directions, and their elements quantitatively determined. An account of these researches must be reserved until after their completion. Other coloured ingredients of bile.

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

Bile.—The remarkable reaction of bile known as Pettenkofer's test has been subjected to a special study, which was thought to be of greater importance, when it was found that cerebric acid yielded the reaction just as well as bile acid.

The products separated at present are :—

(*a.*) Precipitate by absolute ether from absolute alcohol solution. (Salts containing five per cent. of S.)

(*b.*) Do. second precipitate, containing acid soluble in water, giving insoluble barium salt.

Acid, precipitated by hydrochloric acid, giving soluble barium salt.

(*c.*) Salts soluble in mixture of ether and alcohol, yielding oleic acid.

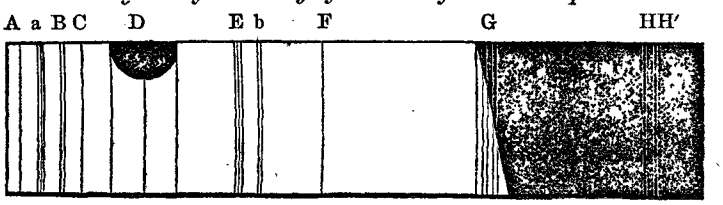
Biliary acid, the essence of reactive power.

Spectrum of bile-test.

The spectrum of the test, which has a peculiar absorption, was determined.

To obtain a very clear solution, acid was employed which had served for producing the test once before. Red slightly shortened. Absorption band in yellow. 142° — 141° 24′ = 0° 36′. (See Plate IV. fig. 8.)

Diagram of Intensity of Pettenkofer's Test Spectrum.



The fluid was prepared by adding a few drops of a concentrated test to a greater bulk of concentrated sulphuric acid until the band could be seen. Another reading gave 142° 6′ — 141° 18′ = 0° 48′. Green much dulled. Blue dulled, but not cut off before its ordinary end. This spectrum has to be studied with Drummond's light, as the colour of the fluid is so intense that a very dilute solution obscures the other parts of the spectrum before the band is quite dark enough to show distinct edges. The band given by cerebric acid in Pettenkofer's test is apparently different. It shows 141° 30′ — 141° = 0° 30′. But this also has to be examined in Drummond's light. It is questionable whether the band of cerebric acid in the purple test is due to the purple, as cerebric acid and lecithine from eggs with sulphuric acid alone yield a brown fluid, which red in dilution, shows a very similar band.

Effect of these researches.

The communication of the extremely intricate details of this difficult research must be reserved for another opportunity.

The researches on cholophæine and biliverdine have determined a series of questions with which most animal chemists have for 30 or 40 years been engaged. The chemistry of the bile in its great features has been thereby completed. The chemistry of diseases in which the bile shows abnormal phenomena has been thereby made more easy. The research on cholera furnishes some evidence of this ; in many biles the colouring matters could be diagnosed as well as the biliary acid, and to the absence of either a due consideration could be given.

Influence on current theories.

Of the influence of these researches on current theories one may be mentioned. The hypothesis that the coloured ingredients of bile were

directly derived from those of the blood has been shown to be devoid of any foundation, particularly the erroneous statement that the cholophæine and biliverdine contained *iron* (Harley) has been completely disproved.

Of incidental researches and operations I must mention—

Analysis of a particular brown human gallstone.

Analysis of mixed human gallstones.

Analysis of a specimen of reputed bile colouring matter from man.

Incidental researches and operations.

Operations for extracting colouring matter from ox bile had to be suspended on account of the danger of a nuisance in the neighbourhood of the laboratory.

Ox bile created difficulties.

Extraction of colouring matter from jaundiced urine.

Many inquiries do not appear in the account, as though they were essential as means for arriving at the truth, they only served to expose previous errors. It is, however, necessary to allude to them in a responsible account, as they include a great number of elementary analyses, which at an early period of the research were the only available tests for the purity of bilirubine and biliverdine, and took up a great amount of time unavoidably, and happily with a positive ultimate result.

Much essential analysis does not appear.

Examination of a Gallstone from a Pig.

Gallstone from a pig.

I subjoin here, as of much interest in relation to some of the matters under discussion, the details of my examination of a large gallstone found in a pig.

The gallstone filled the entire gall-bladder ; it was arranged in concentric layers of light and dark yellow colour. The whole was brittle and fell into fragments on removal. It was powdered. The powder was yellow.

Moisture.

Determination of the Hygroscopic Moisture.—The entire quantity of powder, including the hygroscopic moisture, weighed 17·4 grammes. A quantity of this heated at 120° C. until its weight remained stationary lost 8·28 per cent. of water.

Water extract.

Extraction with Water.—The extraction was repeated to exhaustion, and the filtrates, which were very pale yellow, were condensed. A resinous matter deposited. This was redissolved, refiltered, and the solution treated with sodium sulphate to precipitate hyocholate of sodium. A small quantity of this salt, perfectly colourless and of characteristic properties, was isolated in this manner.

Alcohol extract.

Treatment of Powder with Alcohol.—The washed powder was treated with a large volume of alcohol in the cold. After three days' standing large masses of white crystals were found to have been formed. They were fine needles in stellar groups as seen under the microscope. On boiling they dissolved in the alcohol. The powder was therefore exhausted with this solvent, and all the filtrates were united. After evaporation of the alcohol a quantity of nearly white lime-salt was left, weighing 12·06 grammes. This was repeatedly redissolved and recrystallized from alcohol, and the white portions obtained were subjected to analysis. Heated with potassium it yielded no prussian blue, and was consequently free from nitrogen. On combustion with sodium carbonate, and nitre, no sulphuric acid was obtained, consequently sulphur was absent.

Elementary analyses.

Elementary Analyses of the Salt :—

(1.) 0·328 burned and weighed gave 0·025 calcium carbonate, equal to 0·0143 grammes, or 4·35 per cent. Ca.

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

Cholate, hyocholate, and hyocerosinate of calcium.

(2.) 0·346 grammes burned and treated with $H_2 SO_4$ gave 0·0169 gypsum, equal to 4·8 per cent. Ca.

(3.) 0·1995 grammes burned in lead chromate gave 0·0195 H and 0·1309 C, equal to 65·6 per cent. C and 9·7 per cent. H.

These analyses lead to the formula of cholate of calcium. This is singular, as one should have expected to find the hyocholate, which contains more carbon than the cholate. Some other crystallizations yielded products, which on analysis corresponded to the hyocholate of calcium; one product even by its high amount of hydrogen ($C_{24}H_{48}O_8$) was shown to be a new acid, to which I attribute the name of hyocerosinic acid.

Carbonic acid.

Alumina.

Lime.

Magnesia.

Potash.

Colouring matter.

Chloroform extract.

Part insoluble in Alcohol.—This dried on the filter weighed 3·8 grammes. It was treated with dilute hydrochloric acid, and the gases which were evolved, were passed first through an acid solution of arsenious acid, and then through an alkaline solution of barium salt. The former remained clear, so that the absence of any hydrothion (always present in ox gallstones) was proved. The latter gave a precipitate of barium carbonate. The insoluble part was now separated from the hydrochloric acid solution, and the latter was evaporated to dryness on the water-bath. On resolution in little water and a drop of hydrochloric acid, there remained a residue of mucus and a little alumina. The filtrate gave no precipitate or other reaction with hydrothion. On addition of ammonia an immediate precipitate ensued which was soluble in caustic potash, and re-precipitated by very concentrated hydrochloric acid. It was consequently alumina. The tests for phosphoric acid and iron gave no result. The matters which were soluble in ammonia fell on addition of ammonium carbonate and chloride. The precipitate redissolved in hydrochloric acid gave with sulphuric acid a precipitate of gypsum. Barium or strontium were not present. The matters soluble in ammonium carbonate gave a precipitate with ammonium phosphate containing the magnesia. The filtrate evaporated to dryness and ignited with alcohol showed traces ofpotash.

The part insoluble in hydrochloric acid was put into a flask and exhausted with hot alcohol. It had assumed a different structure. The original light yellow granules had become disintegrated and passing into a brownish colour. They were dried in the steam-closet, and treated with chloroform. A pale yellow solution was obtained which contained very little material, and on distillation of the chloroform left a green solution, in which even on great concentration, no deposit formed. The solution was further examined as follows:—

Green Chloroform Extract.—A large quantity of chloroform boiled with the residue from hog's gallstone assumed a pale yellow colour. After evaporation to a small bulk this solution was of a bright emerald green. In the spectroscope red was cut off at 43, green at 105, and the visible spectrum was all green, yellow and orange being completely overlaid.

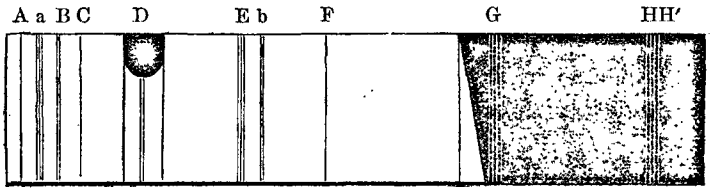
The green solution, shaken with water made alkaline by a drop of caustic potash, yielded all its colouring matter to the water. The alkaline water-solution was purely yellow.

The chloroform solution evaporated left a slight greenish residue, which with nitrous nitric acid gave a purple red reaction, with admixture of blue. The final reaction was not yellow, but colourless.

The watery alkaline solution extracted from the chloroform, after boiling treated with H Cl became blue.

Chemical Characters of the particular Colouring Matter.—Dissolved in alcohol and caustic potash, it forms an intensely yellow solution. This after some standing gives a green precipitate by H Cl. After evaporation of alcohol a yellow matter separates, a blue one remains dissolved. This has a spectrum with a band measuring 55 to 67 = 12. Intens. 3. Yellow to dark green. Blue commences at 106 and reaches to 155. Possibly the band in red extends by a very feeble shade to 81, or even to 88.

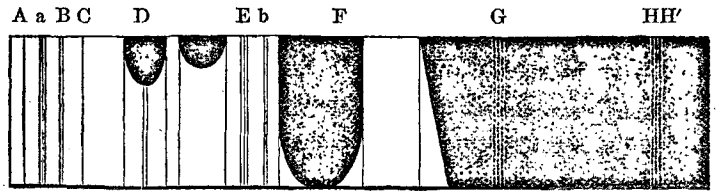
Diagram of Spectrum of Alcohol Solution of Blue Matter or Hyocoeruline.



The yellow colouring matter, hyoflavine, is insoluble in alcohol. Easily soluble in caustic alkali, with a yellow colour. Little soluble in chloroform, with a yellow, after evaporation green, colour. Insoluble in ether, but somewhat soluble in ether and glacial acetic acid.

Nitric Acid Reaction of the Coloring Matter.—This coloring matter was dissolved in alcohol and potash, boiled, and nitric acid added. Red, violet, blue, and green produced from below upwards. The blue solution in spectrum showed three bands. Nitric acid reaction.

Diagram of Spectrum of Nitric Acid Product from Hyoflavine.



1 ·	54 —	66 = 12	Intens.	3
2 ·	70 —	84 = 14	„	2
3 ·	101 —	126 = 25	„	10

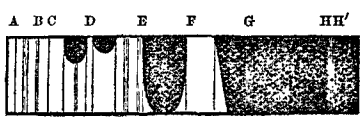
Blue till 142.

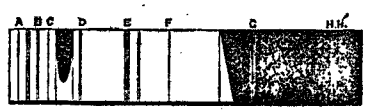
Second band is not completely separated from the first. The green which is free, is broad and beautiful. The solution became on standing more purple, but the bands in spectrum remained the same.

Reaction of Coloring Matter with fuming $H_2 SO_4$.—Green produced, light and beautiful. Diluted with $H_2 SO_4$ solution cuts off end of spectrum to 45. All is green to 110. Blue to 149. No particular bands are discernible. On dilution with water the green colour remains in solution. This test seems to differ from the analogous bilirubine test in this, that the green is of a lighter tint, and that its sulphuric acid solution gives no bands in the spectrum, while cholothalline has two bands. Fuming sulphuric acid reaction.

Comparison of the principal Reactions of

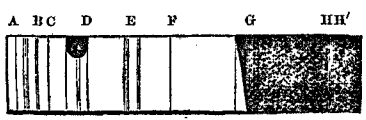
	Hyoflavine.	*Bilirubine.*
Reaction of chloroform solution.	Very little soluble in chloroform, with a yellow colour, becoming green on evaporation.	Comparatively easily soluble in chloroform, with a dark red colour; dilute also yellow.
	Yellow deposit on evaporation to dryness.	Yellow and red deposit on evaporation.
	Spectrum all green, yellow and orange overlaid.	
	Green solution shaken with potash water yields all hyoflavine to water. Light yellow solution.	Red solution yields all bilirubine to potash water. Orange red solution.
	The water solution boiled and treated with acid becomes blue.	The water solution boiled and treated with acid becomes green.
	Slight greenish residue of chloroform solution yields a purple and blue reaction with nitric acid. No yellow at end.	Do. Yellow at end.
	Hyoflavine dissolves in alcohol and potash with an intensely yellow colour. On heating it becomes greenish.	Dissolves in alcoholic potash with orange yellow colour, on heating becomes green.
	From heated solution H Cl precipitates a green matter, which consists of a yellow precipitate, unchanged hyoflavine, and a blue matter, hyocoeruline.	From heated solution H Cl precipitates a yellow-orange matter, which is stained bilirubine, and a green matter, biliverdine, remains in solution.
	By longer heating of the watery alkaline solution all hyoflavine is transformed into hyocoeruline, which falls at once with acids as a blue matter.	By long heating of the watery alkaline solution all bilirubine is transformed into biliverdine, which falls at once as a green matter.
	By nitric acid red, purple, blue and green reaction produced. Blue alcoholic solution has the following spectrum:	By nitric acid red and purple, blue and green reaction. Blue matter in alcohol has spectrum of cholocyanine, here represented.





Hyocoeruline.

Blue in alcohol solution.
Spectrum: One band in red, situated as in the folowing spectrum.



Green produced by H_2SO_4.

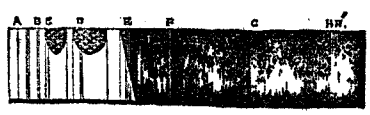
Spectrum: No bands in sulphuric acid solution.

Biliverdine.

Green in alcohol solution.
Spectrum: No band at all.
Red and green divide the spectrum between them.

Cholothalline.

Spectrum: Two bands in green, similar to blood bands.



VII.—Colouring Matters of the Urine.

I found it requisite to undertake an "experimental comparison of various modes of determining the quantity of uric acid in urine." The motives for this research are contained in the paper, to be published elsewhere, and arise out of the necessity to begin the study of the dyscrasias (gout particularly) by means of the best methods only, so that results cannot be called in question upon the basis of the science as it was at the time the research was undertaken.

Uric acid, determination of quantity.

The result of the research is the gain of a much improved method of analysis of uric acid in urine, which, while confirming a part of Lehmann's prescription, is an independent improvement of it and of kindred proceedings.

Improved method.

32 days material to be used for determining urochrome.

The physiological part of the research, extending over 32 days, involved the collection, without loss, of the urine excreted during that time. The uric acid having been determined, there remained valuable material in the shape of the extract of over 40,000 C.C. of urine, which it is intended to use for an attempt to determine the amount of urochrome or colouring matter contained in the urine by the amount of the peculiar products of decomposition of that substance (uromelanine, uropittine, omicholine) obtainable under the influence of acids. This will be carried out as soon as the elementary composition and atomic weights of the two last substances are determined as certainly as that of uromelanine.

Uric acid for chemolytic research.

Uric Acid.—About 12 pounds of urate of ammonium were operated upon, and the uric acid (nearly 5 lbs.) obtained in a pure state. The product is intended to serve for a research on uric acid, particularly those products of its decomposition which like alloxan appear to take a share in important chemical pathological processes.

Para-uric acid.

Para-uric Acid.—In the course of the analyses of a case of malignant jaundice or yellow atrophy of the liver I met with a particular form of uric acid, which crystallised in long silky needles. It was more soluble in water than uric acid, and deposited from it on addition of hydrochloric acid. Like para-benzoic acid it gradually changed into ordinary acid while being repeatedly recrystallised.

New alkaloid in human urine.

New Alkaloid in Human Urine.—The search for an alkaloid in tetanus necessitated a parallel examination of healthy human structures and fluids, of which that concerning the urine has resulted in the discovery of a new organic alkaloid. The several processes for the separation of alkaloids, from animal tissues were at the same time subjected to a scrutiny. It remains to be seen in what relation this alkaloid stands to omicholine, a remarkable substance lately extracted from urine, and the analysis of which is not yet completed.

Urochrome products from putrid urine.

Urochrome.—The researches on the coloured ingredients of the urine were continued upon 60 quarts of putrid urine. A quantity of all the usual decomposition products, fixed and volatile, were extracted, but uromelanine alone could be advanced to final analysis, as stated in the essay on that body. During the summer of 1866, some six gallons of fresh urine from healthy adult male persons living regularly were evaporated daily, and after having undergone the several processes formerly described by me, the extracts were treated for the decomposition products which it was desired to obtain.

Preparation of Uromelanine from Putrid Urine. — Pure human normal urine is put into a sulphuric acid flask, or carboy, and allowed to

decompose during 12 months. During this time the bottle is kept well stoppered. The clear fermented urine is then drawn off with a syphon, and without filtration immediately evaporated on the steam-bath. During evaporation the formerly clear and yellow urine assumes a dark brown nearly black colour. The concentrated liquid can scarcely be filtered. It is at once treated with sulphuric acid in the cold, which precipitates uromelanine, uropittine, omicholine, and much benzoic acid. The precipitate collected on a filter is exhausted first with boiling water, which removes benzoic acid and other soluble matters; next with boiling alcohol, which takes up uropittine and omicholine. There remains impure uromelanine as a black powder. This is now dissolved in a little caustic potash and much water, and filtered. This process of filtration constitutes the greatest difficulty of the operation, as the mucus suspended in the fluid quickly obstructs the filters. It is therefore necessary to dilute the fluid very much, to let the mucus settle in high beakers, and to filter only the upper clear layers, to the exclusion of the lowest ones. Every filter which becomes clogged should be immediately replaced by a fresh one. The solutions should be allowed to stand, and be refiltered so often that ultimately they will pass easily and without residue through fresh filters. To the clear dark red, in reflected light black solution, sulphuric acid is now added, until the uromelanine falls in flakes and the fluid has an acid reaction. The liquor, after the bulky precipitate has settled, is drawn off by means of the syphon, and washing effected by water and subsequent decantation. Finally the precipitate is stirred up five or six times with strong alcohol, and the alcohol drawn off by the syphon as many times. Ultimately the purple black matter is collected on a filter, washed with alcohol, and dried.

Uromelanine from putrid urine.

Properties of uromelanine from putrid urine.

The properties of uromelanine thus obtained are identical with those of uromelanine from fresh urine. In particular it is insoluble in water; very little soluble in alcohol, but imparts to this agent a dark red colour, in the cold while it is in its bulky condition, but when contracted and pulverulent boiling is necessary to colour the alcohol. It is very easily soluble in dilute caustic alkalies, ammonia and potash, and precipitated by any acid. From its solution in the smallest quantity of ammonia it is completely precipitated by most soluble salts of the earths and metals. The ammoniacal solution of nitrate of silver produces no precipitate in the ammonia solution of uromelanine, but the precipitate appears on the addition of acetic acid.

Properties of uromelanine in general.

Uromelanine, whether prepared from fresh or putrid urine, is soluble in acetic acid, more in hot than in cold; and from this solution nitrate of mercury precipitates a red matter. On dry distillation it gives out white fumes, which condense to an oil, but no sublimate of any kind is obtained. The fumes or oil are neutral, bleaching rather than changing, like acid or alkali, the colour of litmus. They give no aniline reaction, but with nitrate of mercury they give an exquisite red reaction and precipitate. A very voluminous dense charcoal of the bulk of the original particles remains.

Uromelanine dissolves in nitric acid with a dark red brown colour. Red vapours are evolved on boiling, but the reaction is not violent even with much acid. After long boiling the solution is yellowish red. Addition of water produces a fawn precipitate which is entirely soluble in alcohol, and with ammonia and barium chloride gives a voluminous yellow precipitate. When the nitric acid is evaporated two matters are left, one soluble in alcohol the other insoluble. The solution gives the red reaction with nitrate of mercury.

Concentrated fuming sulphuric acid easily dissolves uromelanine, forming a red or purple solution. Immediate addition of water preci-

pitates all coloured matter, and the liquid is white and clear. But when the concentrated mixture is allowed to stand over night, water precipitates a coloured portion ; another coloured portion remains dissolved. Carbonate of barium precipitates all coloured matter on boiling, and the filtrate is again white.

Recently precipitated uromelanine suspended in water and subjected to the action of chlorine yields a brownish substance, soluble in boiling alcohol. While the spirit is being heated, some of the substance melts to a brown resin, which dissolves by continued heating with new alcohol. The solutions added together yield on cooling yellowish red amorphous flakes. These flakes are not again entirely soluble in alcohol, probably because the chloro-compound undergoes a change during the heating with the alcohol and subsequently. This supposition was confirmed by the results of elementary analysis.

List of preparations.

List of Preparations of Uromelanine referred to in this Research.

1. *Prize Essay Preparations.*

From fresh urine.	By boiling with H_2SO_4	A. I.	Element. analyses, neutral barium salt ; zinc salt; lead salt.
		A. II.	Silver salt ; barium salt.
From putrid urine.	By addition of H_2SO_4, no boiling.	A. III.	Silver salt ; barium salt; calcium salt.

2. *Preparations made specially for the present Research.*

From fresh urine.	By boiling with H_2SO_4	B. I.	
		B. II.	2 Elementary analyses.
		B. III.	
	Before boiling	C. I.	
	After boiling with H_2SO_4	C. II.	6 Elementary analyses.
	Before boiling	D. I.	2 Elementary analyses. Silver salt.
	After boiling with H_2SO_4	D. II.	Calcium salt ; zinc salt.
		D. III.	
		D. IV.	2 Elementary analyses. Silver salt ; barium salt ; zinc salt.

From the notes on the left it will be seen that uromelanine from putrid urine, A. III., and C. I. and D. I. from fresh, were obtained without boiling, by the mere addition of acid to the concentrated liquid. All the other specimens required boiling of the mixture for their formation. The notes to the right of the numbers indicate the analyses and combinations to which they were subjected.

Synopsis of uromelanates.

Synopsis of Uromelanates produced for this Research.

Silver Salts.

Ur.	:	Ag.	Ag. found.	Preparation employed.
1	:	1	13·38 per cent.	A. II., A. III.
2	:	3	18·56 „	D. I.
3	:	5	20·45 „	D. IV.

Barium Salts.

Ur.	:	Ba	Ba found.	
5	:	2	7·20 per cent.	D. IV.
2	:	1	9·05 „	A. I., D. IV.
4	:	3	13·28 „	A. II., A. III.

Calcium Salts.

Ür.	:	Ca	Ca found.	
5	:	2	2·03 per cent.	D. I.
4	:	3	4·35 „	A. III.
2	:	3	7·27 „	D. I.

Zinc Salts.

Ür.	:	Zn	Zn found.	
3	:	1	2·82 per cent.	D. I.
5	:	2	3·54 „	A. I.
2	:	1	4·42 „	D. IV.

Lead Salt.

Ür.	:	Pb	Pb found.	
3	:	2	15·70 per cent.	A. I.

Composition of uromelanine.

Elementary Composition of Uromelanine.—From the analyses of preparations A. I., A. III., D. I., D. IV. (leaving C. II. at present out of the calculation), and from the two-thirds basic silver salt Ür : Ag = 3 : 5, it follows that uromelanine is $C_{36}H_{43}N_7O_{10}$.

Theory of atoms.		Per cents.	Found mean.
C_{36}	432	58·93	57·21
H_{43}	43	5·86	5·74
N_7	98	13·36	12·88
O_{10}	160	21·85	24·17
	733	100·00	100·00

Silver-compound. (Ür Ag.)

Normal or neutral Uromelanine-silver.—Ür : Ag = 1 : 1. A neutral ammoniacal solution of uromelanine was prepared by evaporating a dilute solution of the substance in ammonia water to dryness on the water-bath, and extracting the salt which had remained soluble from the uromelanine which had become insoluble by the loss of ammonia by means of water. This dark brown solution was precipitated by silver nitrate, the precipitate contracted by heating in the fluid, washed by decantation, then on the filter, and dried in the steam-closet. The compound had the composition expressed by the formula $C_{36}H_{40}AgN_7O_9$; it was therefore Ür + Ag — H_3O, or an atom of water had left upon the substitution of an atom of hydrogen by one of silver.

Theory of atoms.		Per Cents.	Mean found.
C_{36}	432	52·55	52·41
H_{40}	40	4·86	5·15
N_7	98	11·92	12·47
O_9	144		
Ag	108	13·13	13·38
	822		

Silver-salt. ($Ür_2 Ag_3$.)

Half-basic Silver-uromelanate, Ür : Ag : : 2 : 3.—Uromelanine was dissolved in a minimum of ammonia, and the solution digested with an excess of uromelanine which remained undissolved. The solution was now boiled for a long time; as on cooling a slight deposit ensued the solution was filtered. It was then precipitated with silver nitrate, washed and dried at 100° to 105°. It yielded 18·57 per cent. of Ag,

and contained, therefore, exactly two $\tilde{U}r$ upon three silver. Or it consists of one atom of neutral and one of basic salt.

$$\begin{array}{lr} 2 \text{ uromelanine} - 3H = & 1{,}463 \\ 3 \text{ silver} & 324 \\ \hline & 1{,}787 \end{array} = \begin{cases} \tilde{U}r + Ag \\ \tilde{U}r + \begin{cases} Ag \\ Ag \end{cases} \end{cases}$$

Silver-compound. ($\tilde{U}r_3\ Ag_5$.)

Two-thirds basic Silver-uromelanate.—$\tilde{U}r : Ag :: 3 : 5$. Some uromelanine was dissolved in concentrated ammonia water, and after having been boiled down to one-half was precipitated with silver-nitrate. The filtrate and first washing water were colourless, but the later washings became progressively darker. These dark filtrates, however, contained no trace of silver. The preparation contained 20·1 per cent. of Ag. It was therefore clear that the ammonia could not be sufficiently removed from a uromelanine solution by boiling down to one-half. A third of the same solution was treated with $\text{Ba}\ Cl_2$, and yielded the neutral barium compound, as if the solution had been strongly alkaline. A second preparation was therefore made as follows: The uromelanine was dissolved in ammonia and the solution was evaporated, not as in the first preparation only to one-half, but to dryness. The residue easily dissolved in water, leaving but an insignificant quantity of insoluble matter behind. This circumstance pointed to the presence of enclosed alkaline salt. The filtered fluid was treated with silver-nitrate, and the flocculent precipitate washed on a filter. The first filtrate was colourless, the subsequent washings slightly coloured. Its analysis led to the following data:—

Pentargyric Triuromelanine.

	Atomic Weights.	Required in 100.	Found mean.
C_{108}	1,296	47·40	46·90
H_{124}	124	4·53	4·77
Ag_5	540	19·75	19·77
N_{21}	294	10·75	10·36
O_{30}	480	17·57	18·20
	2,734	100·00	100·00

This result by the following formula $\frac{2{,}734 - 540 + 5}{3} = 733$ leads to the atomic weight of uromelanine as also determined by other analyses. But this silver salt is the firmest basis for that theory, as it is very definite, and has been analysed repeatedly regarding its four directly determinable elements. The means found correspond in a remarkable manner with the requirements of theory.

Barium salt. ($\tilde{U}r_5\ Ba_2$.)

Half-acid Barium-uromelanate.—$\tilde{U}r : Ba = 5 : 2$. $\tilde{U}r$ was dissolved in excess of concentrated ammonia, and precipitated by $\text{Ba}\ Cl_2$. It was washed during more than a week with nearly 100 portions of water, before it became steady and the filtrates were free from Ba.

	Theory of Atoms	in 100.	Found.
C_{180}	2,160	54·89	52·96
H_{211}	211	5·36	5·5
N_{35}	490	12·44	11·88
O_{50}	800		
Ba_2	274	6·96	7·2
	3,935		

Barium salt. ($\tilde{U}r_2$ Ba).

Neutral Barium Uromelanate.—$\tilde{U}$: Ba = 2 : 1. A dilute strongly alkaline solution of uromelanine was treated with barium chloride, the precipitate washed with water and dried. A second preparation was made from the same specimen by boiling its strongly alkaline solution down to one-half, and then precipitating it by Ba Cl_2. During washing the coloured filtrates became darker, and the Ba ceased to be contained in them, before uromelanine. The precipitate was washed with alcohol, dried, and analysed.

Theory of Atoms		in 100.	Mean found.
C_{72}	864	53·96	"
H_{84}	84	5·24	"
N_{14}	196	12·24	11·3
O_{20}	320	"	"
Ba	137	8·55	8·34
	1,601		

Barium salt. ($\tilde{U}r_4$ Ba_3).

Tribarytic Tetrauromelanine.—$\tilde{U}$r : Ba = 4 : 3. The precipitation of this barium salt has to be effected in a solution containing a minimum of ammonia, otherwise the gelatinous precipitate retains ammonia longer than the excess of chloride of barium, and the alkali then decomposes a small quantity of the combination, so that the filtrates which at first are colourless become darker as the washing proceeds. The first washing is therefore best effected with water containing a little chloride of barium, and ultimately the washing is completed with alcohol. The compound consists of one molecule of basic and one molecule of neutral uromelanate.

$$\left.\begin{array}{l} \tilde{U}r\ Ba \\ \tilde{U}r\ Ba \\ \hline \tilde{U}r \\ \tilde{U}r\ Ba \end{array}\right\} = C_{144}\ H_{166}\ Ba_3\ N_{28}\ O_{40}$$

$$4 \times 733 = 2{,}932 - 6 = 2{,}926$$
$$+\ 3\ Ba \quad = \quad 411$$

Molecular weight of compound = 3,337

This theory derives great support from the constitution of a calcium compound to be described lower down.

Calcium salt. ($\tilde{U}r_5$ Ca_2).

Half-acid Calcium-uromelanate.—$\tilde{U}$r : Ca : : 5 : 2. The ammoniacal solution was made neutral by digesting it with excess of uromelanine, and after filtration boiling it, and filtering again from a little deposit which had formed. $\tilde{U}r$ 733 × 5 = 3,665 + 2Ca = 80 − 4H = 3,741 requires 2·13 per cent. Ca, found 2·03 per cent. Ca.

Calcium salt. ($\tilde{U}r_4$ Ca_3).

Tricalcic Tetrauromelanine.—$\tilde{U}$r : Ca = 4 : 3. In the preparation of this salt the same precautions have to be observed which have already been mentioned under uromelanine-barium. It has to be washed with water containing chloride of calcium, and ultimately the excess of

hloride has to be removed by alcohol. The compound is exactly analogous to the tribarytic tetrauromelanine, and its formula is

$$\left.\begin{matrix}\left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\text{Ca}\\ \left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\text{Ca}\end{matrix}\right\} = \text{C}_{144}\,\text{H}_{166}\,\text{Ca}_2\,\text{N}_{28}\,\text{O}_{40} = \text{Mol. W. } 3{,}046.$$

Tricalcic-diuromelanine, or Hyperbasic Calcium-uromelanate.— $\tilde{U}r : Ca :: 2 : 3$. The strongly alkaline solution was precipitated with $Ca\,Cl_2$ and dried at 100°. Calcium salt. ($\tilde{U}r_2Ca_3$).

1,466 − 6 + 120 = 1,580, requires in 100° Ca 7·59, found mean 7·33.

$$\left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\left.\begin{matrix}\text{Ca}\\ \text{Ca}\\ \text{Ca}\end{matrix}\right\} = \text{C}_{72}\,\text{H}_{80}\,\text{Ca}_3\,\text{N}_{14}\,\text{O}_{20}.$$

Acid Zinc-uromelanate, or Monozinc Triuromelanine.—$\tilde{U}r : Zn :: 3 : 1$. A quantity of $\tilde{U}r$ was dissolved in ammonia and made neutral by boiling for 1½ hours. The vapour then did not give any fumes with the H Cl glass rod. Sulphate of zinc was employed for the precipitation. Analysis yielded 2·82 per cent. Zn, which leads to the following theory :— Zinc-salt. ($\tilde{U}r_3\,Zn$.)

$$\begin{aligned} 3\,\tilde{U}r - 2\,H &= 2{,}197 \\ +1\,Zn &= \phantom{2{,}}65 \end{aligned}$$

1 mol. of compound = 2,262 requiring in 100 2·87 per cent. Zn.

$$\left.\begin{matrix}\left.\begin{matrix}Ur\\ \tilde{U}r\end{matrix}\right\}\text{Zn}\\ \tilde{U}r\end{matrix}\right\} = \text{C}_{108}\,\text{H}_{127}\,\text{Zn}\,\text{N}_{21}\,\text{O}_{30}.$$

Normal Zinc-uromelanate.—$\tilde{U}r : Zn :: 2 : 1$. Some uromelanine was dissolved in concentrated ammonia and after having been boiled to drive off the excess of ammonia was precipitated with zinc sulphate. The filtrate and first washing water were colourless, but by progressive washing the water became darker. As these filtrates contained no zinc the washing was arrested and the compound dried. The zinc was determined as oxyde by combustion, and found to amount to 4·42 per cent. Zn. This leads to the formula $C_{72}\,H_{84}\,Zn\,N_{14}\,O_{20}$ M.W. = 1,529. Zinc salt, ($\tilde{U}r_2\,Zn$).

The solution employed in this experiment was one-third of a solution, the other third of which yielded the second preparation of normal or neutral barium-uromelanate, which contained 8·03 Ba. The last third of the solution by treatment with silver-nitrate yielded not a normal but a two-thirds basic silver-salt, or pentargyric triuromelanine with 20·11 per cent. of Ag, or a trifle in excess of the theory.

Half-acid Uromelanate of Zinc.—$\tilde{U}r : Zn :: 5 : 2$.—A preparation was made by adding $Zi\,SO_4$ to a filtrate from uromelanate of ammonia which during evaporation had lost ammonia, and deposited a portion of its uromelanine in scales. Another preparation was obtained by treating the mother liquors from urochrome preparation with lime, ultimately with $Zi\,Cl_2$ to separate creatinine. The creatinine-chloride of Zinc salt, ($\tilde{U}r_5\,Zn_2$).

APPENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

zinc deposit was washed, and then dissolved in boiling water. A gelatinous brown precipitate remained undissolved, and was found to be uromelanine-zinc by analysis. The molecular weight of this salt is $2\,\text{Ƶi} = 130 + 5\,\text{Ur} - 4\,\text{H} = 3{,}661$, total $= 3{,}791$. This requires 3·42 per cent. Ƶn. Found 3·54 per cent.

It may be considered as a compound of two molecules of neutral zinc uromelanate and one molecule of uromelanine. Thus :—

$$\left.\begin{array}{l}\left.\begin{array}{l}\tilde{\text{Ur}}\\ \tilde{\text{Ur}}\end{array}\right\}\text{Ƶn}\\ \left.\begin{array}{l}\tilde{\text{Ur}}\\ \text{Ur}\\ \tilde{\text{Ur}}\end{array}\right\}\text{Zn}\end{array}\right\}=\text{one molecule of dizincic penta-uromelanine.}$$

Lead salt, ($\text{Ur}_3\,\text{Ᵽb}_2$)

Half-basic Uromelanate of Lead.—$\tilde{\text{Ur}} : \text{Ᵽb} :: 3 : 2$. A solution of uromelanine from fresh urine in ammonia was made, so neutral that some uromelanine remained undissolved. To the clear filtrate neutral acetate of lead was added. The precipitate was perfect, the filtrate colourless. The precipitate was washed until the filtrates were free from lead.

Molecular weight of this compound :—

$$\overbrace{3\,\tilde{\text{Ur}}}\quad - 4\,\text{H} + 2\,\text{Ᵽb}$$

$$733 \times 3 - 4 + 414 = 2{,}609.\ \text{M. W.}$$

$$\text{ƀ required in } 100 = 15{\cdot}86.$$

$$\text{" found " } = 15{\cdot}703.$$

$$\left.\begin{array}{l}\left.\begin{array}{l}\text{Ur}\\ \tilde{\text{Ur}}\end{array}\right\}\text{Ᵽb}\\ \tilde{\text{Ur}}\quad\text{Ᵽb}\end{array}\right\}=\text{one molecule of diplumbic tri-uromelanine.}$$

The Origin and Physiological and Pathological Significance of Uromelanine.

Uromelanine is not as such contained in urine, but is a product of the decomposition by putrefaction, or the influence of sulphuric acid and time, or sulphuric acid and heat of another substance contained in it. This original substance is urochrome, the colouring matter. When urochrome splits up into its constituents under the influence of putrefaction it does not immediately yield uromelanine, but a less oxydised substance of light yellow colour, which on exposure to oxygen quickly becomes brown ; and during evaporation of the putrid urine, while exposed to air, assumes a perfectly black colour, and is in part precipitated.

It is this melanigenous substance together with the carbonate of ammonia which gave to putrid urine its value in indigo-dyeing ; the ammonia dissolved the indigo, the melanigene reduced it, the textures to be dyed were now steeped, and on subsequent exposure to air assumed the indigo-blue colour. As 300 pounds of good putrid urine were required to dissolve and reduce one pound of indigo, it is possible to form a rough guess of the quantity of melanigene present in that quantity of urine, supposing melanigene to be the only oxydisable substance present in putrid urine.

Uromelanine probably contained in melanotic tumours.

Late researches instituted in the hospital at Prague have made it probable that melanigene or melanine are regular ingredients of melanotic tumours, particularly the cancers of that class. It is true that the "melanine," which the Prague observers extracted from the urine

of patients suffering from melanotic cancer, is nothing else than the uromelanine which can be obtained from all urine. But as they assert to have obtained the same substance from the tumours themselves a remarkable inquiry is opened.

In his analyses of the pigment of the choroidea, Scherer had found results which it is interesting to compare with those yielded by uromelanine.

Melanine of the eye.		Ür.	Theory of Ür.
C	58·28	57·21	58·93
H	5·92	5·74	5·86
N	13·77	12·88	13·36
O	22·03		

The composition of melanine is, therefore, very similar to that of Ür. as found, and more so to that calculated from its compounds.

Rosow, however, at a later period found in the pigment of the choroidea, Heintz in pigment from melanotic tumour—

Pigment of choroidea.		Melanine of tumour.	
C	54·0	C	53·44
H	5·3	H	4·02
N	10·1	N	7·1
O	30·	O	35·44
Ash	0·6		

As Rosow did not analyse a pure preparation, we cannot attribute the same value to his analyses as to those of Scherer.

Uromelanine, why remarkable.

As the most general result of these new researches we make the acquaintance of one of the most interesting and remarkable compounds in the whole range of organic chemistry. The distinction here claimed belongs to uromelanine in the first instance, by reason of its atomic weight, which is 733. There are but very few organic substances which attain so high a number of carbon atoms as 36, and still fewer which combine with that number, besides hydrogen and oxygen, seven atoms of nitrogen. Uromelanine is a very stable body compared to any compound of similar atomic pretensions, and combines readily in a great variety of proportions with very different bases. Its derivates of a substitutive or otherwise metamorphic quality promise to be very great in number, and invite the chemist to attentive study. But by far the greatest interest attaches to uromelanine as an animal matter, and particularly as that animal product which amongst all decomposition products of excretory substances of the animal economy occupies by its atomic weight and complicated constitution the highest place. Another element of the importance claimed for this substance is the circumstance that it affords an imperturbable basis for the operations which animal chemistry will have to undertake in order to determine the nature, composition, and atomic weight of the colouring matter of urine. This latter must necessarily have a higher atomic weight than 733, and possess a constitution of singular complication and variety as regards the nuclei or radicals contained in it. Then if our ideas about the nature of excretory substances are correct in their application to urochrome no less than to uric acid, we are driven to the assumption that as uric acid is a derivate of albumen, so urochrome is a derivate of a constituent of the blood of much higher atomic complication than albumen, and as such we could claim only one material, namely, the most characteristic ingredient of the blood corpuscles, or hematocrystalline, the crystallisable compound which may be split up into an albuminous body and into

Uromelanine firm basis for studying urochrome.

Urochrome possibly derived from cruorine.

hematine. We thus may obtain, probably, a new means of estimating the effects of the febrile process upon the organ of oxygenation, the blood-disk, or its ally, the myochrome or red colouring matter of the muscles. But we also obtain by a direct process of reasoning a new insight into the chemical processes of life altogether. If uromelanine is of atomic weight 733, its precursor urochrome could not be a derivate of albumen with atomic weight 1,612, or of fibrine with atomic weight 2,200, but would have to be derived from a compound of much higher chemical constitution. This could not be hematine, but solely hematocrystalline, to which we now begin to attribute the importance of being a chemical compound of about 13,000 atomic weight. Hitherto we had been taught that the animal was not a chemical machine with a synthetical tendency of higher aim than the production of fat or wax from sugar and starch. It was believed to receive all its materials, its albumen, caseine, cerebric acid, in a ready-made condition from the plant; no doubt it organized them in the shape of tissues, but it was believed incapable of chemical synthesis of a high order. We shall now have to change these views completely. The highest atomic weight produced in the plant is about 2,200, the highest atomic weight produced in the animal is about 13,000. The complication of the material of the most developed chemical machine of the animal is six times greater than the most complicated material produced in the vegetable economy.

Probable high atomic weight of cruorine.

New philosophy regarding animal synthesis being higher than that of plants.

Paramelanine.

As in spectroscopic analysis of inorganic matters light shoots up here and there for an instant, marking the presence of a minute amount of some matter or other, so in general analysis a few collateral products are met with which indicate their own existence, but at the same time a genetic coherence of the matters under investigation. While uromelanine preserves no reminiscence in its optical characters of the hematine to which it has such particular similarity by its stability and high atomic weight, there is accompanying it a small amount of a substance, which when treated with sulphuric acid yields the spectrum of cruentine.

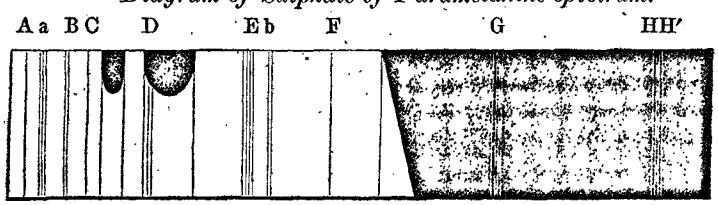
Body accompanying uromelanine yields the spectrum of cruentine.

Paramelanine.

This body I term paramelanine. It was obtained in the following manner. Uromelanine, after separation from the products soluble in alcohol, was dissolved in potash and re-precipitated by sulphuric acid. It was washed with water, lastly with alcohol. These alcoholic solutions had stood a long time and deposited a black matter. This was found to have become insoluble in ammonia. Dissolved in concentrated sulphuric acid it showed a spectrum with two bands.

1. $142\ °6' - 141°\ 54' = 0°\ 12'$
2. $141°\ 45' - 141°\ 15' = 0°\ 30'$

Diagram of Sulphate of Paramelanine spectrum.



The two bands are therefore of the same breadth as those of cruentine-sulphate, but they are situated 0° 12′ more towards the violet. On addition of water the solution remains clear, and the dilute liquor retains

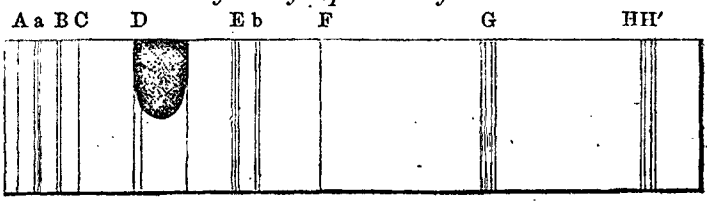
the bands. It has not yet been possible to cause this body to undergo the transformations of cruentine, as its quantity is too small in comparison with the impurities with which it is mixed. What little can be extracted from the original residue by ammonia exhibits no bands.

Omicholine and Omicholic Acid.

Conjointly with uromelanine and paramelanine there are obtained from urine by the chemolytic process other bodies, of which uropittine shows no particular spectral phenomena. The more remarkable are the spectral phenomena of omicholine and omicholic acid.

Omicholine. Omicholine is a part of the resinous product which is soluble in alcohol and ether. It is insoluble in ammonia, and does not combine with bases. It dissolves a little in boiling water. It is exceedingly difficult to obtain it pure. Many analyses of several specimens have led to an average empirical formula $C_{22}\ H_{35}\ NO_3$. It has a powerful odour, most apparent on heating, and when a little only is burned fills the room with the peculiar odour of burned urine. Its solution in ether has a fine ruby red colour, and shows a band in green, 141° 42′ – 141° 12′ = 0° 30′. Near to it in green there is a shading. What ought to be the blue part of the spectrum is strikingly violet. This peculiarity indicates the fluorescent character of the matter which we accordingly discover. In the sun-cone the red solution fluoresces green, thus offering the reverse of the phenomena of chlorophyll, which is green and fluoresces red.

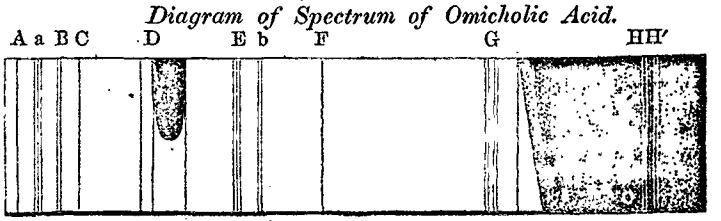
Diagram of Spectrum of Omicholine.



The general impression of this spectrum (see Plate IV. fig. 1) is that it consists of three parts, of which the red and yellow are very light; then follows the green part with the band, and lastly a violet end without any blue.

Omicholic acid. Omicholic acid is that part of the resinous products soluble in alcohol which is soluble in ammonia, and thereby separated from omicholine. It is very similar to omicholine, and one is probably derived from or closely related to the other, although they differ very much in chemical composition. For the average of many analyses of omicholic acid has led to the empirical formula $C_{15}\ H_{23}\ NO_4$. The ether-solution of omicholic acid has a band in green, 141° 36′ – 141° 18′ = 0° 18′

Diagram of Spectrum of Omicholic Acid.



The blue part of the spectrum (see Plate IV. fig. 2) is coloured violet. The entire spectrum makes the impression of being divided into two parts

by the band, one being very light, the other shady and containing only little violet instead of blue. The chloroform solution has the same spectrum, but the second part is almost entirely obscured. The ammoniacal solution of omicholic acid has no bands in the spectrum. Omicholic acid is red, and fluoresces green, but there are slight differences in its phenomena from those of omicholine.

In order to exhibit the differences of the spectra of these substances from those of choleraic urorubine and urocyanine (see Plate III. figs. 2 and 3), I subjoin diagrams of the latter :—

Diagram of Spectrum of Choleraic Urocyanine.

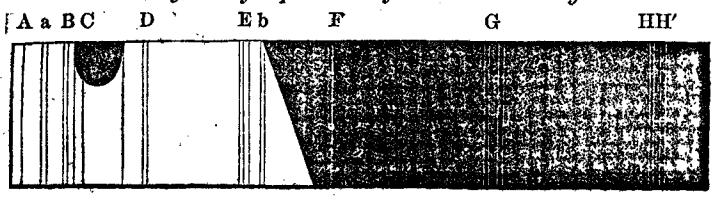
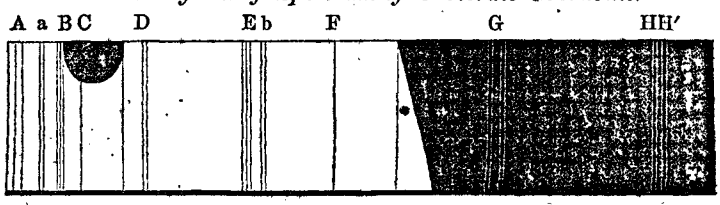


Diagram of Spectrum of Choleraic Urorubine.



Determination of the Quantity of Uromelanine obtainable from healthy Urine.

Quantity of uromelanine in healthy urine.

The whole amount of urine passed by a healthy man in 24 hours, amounting to 2,072 cubic centimetres, was evaporated to a syrupy consistency, and then some dilute sulphuric acid added to it. After 24 hours' standing the precipitate was separated, and found to consist of uric and hippuric acid, coloured brown by a little colouring matter. The filtrate was mixed with a little more sulphuric acid and distilled on the sand-bath. The first portion of distillate had a penetrating odour, and was yellow; over night it became darker. The later distillates were almost colourless, and remained unaltered. The fluid in the retort was filtered from the formed deposit, the latter washed, and extracted with alcohol. What remained insoluble, uromelanine, was dried at 105°, and found to amount to 0·7315 grammes. The alcoholic extract, containing omicholine, omicholic acid, and uropittine after evaporation of the alcohol, amounted to 0·3472 grammes.

This being the first attempt to determine the physiological quantities of the ingredients of urine which yield uromelanine, it would be hazardous to state conclusions. It is remarkable that the quantity of uromelanine obtained from a day's urine is about equal to that of the uric acid excreted on an average under similar conditions.

Uromelanine, &c., in a case of Tropical Fever.

Uromelanine in tropical fever.

A gentleman, a coffee planter from the south of India, was obliged by unceasing attacks of fever to return to England. He arrived

emaciated, with a yellow coloured skin peculiar to the subjects of tropical fever. His tongue was much furred; the liver was so greatly enlarged that the probability of its containing an abscess had been suggested. The urine was of a deep red colour, and deposited urates. The urine from two days was subjected to the chemolytic process described in the foregoing. During boiling of the products in alcohol a small quantity was lost by bumping, the quantities found by weight are therefore only approximatively correct, but can be assumed as such.

Uromelanine found - -	0·2915	grammes.
or per 24 hours - - -	0·14575	„
Uropittine and omicholine - -	0·1242	„
or per 24 hours - - -	0·0621	„

The products soluble in alcohol stand therefore to the uromelanine in the same relation of quantity as in the healthy urine. The total quantity of products was certainly less than from healthy urine, although the actual amount, owing to the accidental loss, cannot be accurately stated.

This urine yielded no uric acid whatever, and the filtrate from the uromelanine was unusually dark, as if it contained an abnormal colouring matter in solution.

VIII.—STUDIES OF THE URINE IN MORBUS ADDISONII.

A woman, *J. T.*, formerly a servant at the Shorlane workhouse, was admitted into the Middlesex Hospital, under Dr. Sanderson, September 16th, 1867.*

Family history.—Father died of hemorrhoids at the age of 40, mother of diseased heart at 60. One brother met with his death accidentally, another died of some chest affection, and a sister, still living, enjoys good health.

Previous history.—When 14 years of age had typhus. Was born in Scotland, but for the last six years has lived in London, and has been subject to occasional catarrh with cough, but without expectoration. Her patella was once fractured, and she says that three years ago she strained her back while turning a mangle, causing lameness for a time, and being followed by pain in mid-dorsal region, which lasted some two or three months. In July 1866 she fell downstairs, had hemophysis two or three days after, and felt pain in the back for a week or 10 days.

History of present illness.—About a year ago caught cold, which lasted some four months, after which felt weak, drowsy, and languid, symptoms which appear to have been gradually coming on from the time she first took cold, for she states that six weeks after her present illness commenced she had nausea and vomiting which lasted for three months without intercession, but these symptoms were accompanied with, and also preceded by, much languor and drowsiness.

After three months of continuous sickness, two months elapsed, during which patient did not vomit at all, but the general weakness with drowsiness and languor still continued; moreover, gradually increasing palpitation after slight exciting causes was now for the first

* My thanks are due to Dr. Sanderson for kindly having afforded me opportunities of observing this remarkable case, and to Dr. King, resident physician to the Middlesex Hospital for the great care and regularity with which he transmitted to me the daily records of the case, and the specimens of excretions submitted to analysis.

time noticed. The nausea and vomiting then returned, and lasted about seven weeks, during which time there was sickness after food regularly once or twice a day. At this time also she complained of pain in the knees and ankles, but nowhere else.

There followed a period of entire freedom from nausea and vomiting, which lasted till two weeks before her admission, nevertheless she always felt tired and sleepy. Patient gave up work in August 1866, but took another place for a couple of months, which she resigned owing to present illness. She has lately been spending her time at Hammersmith for the benefit of her health. A fortnight ago sickness recommenced, but lasted one day only. There has been some dyspnœa on exertion for the last seven months. Catamenia are regular but scanty and pale. Patient first observed that she was getting darker about three months ago, and some six weeks before that thought she was slightly jaundiced, as there was a yellowish tinge about the face.

State on admission.—Pulse, 84; resp. tranquil; B. confined, stools somewhat hard; mucous membranes of hard palate discoloured and darkened. Skin of face, neck, and hands of a dark olive brown colour; that of trunk and lower extremities discoloured in a less degree; beneath the chin and at the left side of the neck a few morbidly white patches may be observed. No pain or tenderness in hypochondria or loins. Hepatic dulness normal.

Phys. signs.—There is impaired resonance of the right supra scapular fossa. It is also doubtfully defective below either clavicle, where expiratory murmur is somewhat harsh, and heart sounds are abnormally distinct, but no moist râles are audible. At the bases partial resonance extends downwards to level of 11th spina; and in tracing the limit of resonance forwards it is found to extend upwards and forwards from the outer edge of the scapula as far as the axillary line, then it turns downwards and forwards towards the præcordia. Sub-tubular breathing with crackles in dull region. Heart sounds feeble, with a faint soft systolic bruit at 4th left costal cartilage.

Sept. 26th.—Slept well last night, and did not vomit till after breakfast this morning, and then only to a small extent. B. regularly open.

Sept. 27th.—The vomiting returned during the night, and there was some sickness after breakfast, but none since dinner. P. 72. Tongue clear, some coolness of extremities and drowsiness.

Sept. 28th.—Was very sick during the night.

29th.—No sickness since yesterday morning. B. not open for three days, aspect languid and listless, evidently does not like to be disturbed, but answers questions correctly. P. 78, very thready and feeble.

30th.—Vomited a little after tea and supper last evening, and again after breakfast this morning; slept well; P. 70; still complains of tenderness and pressure over lower dorsal and upper lumbar spinas; B. not yet open.

Oct. 2nd.—Vomited scarcely at all yesterday, and passed a tolerably good night. Complains of some vertigo this morning. P. 70.

3rd.—Slept fairly, and complains of feeling very drowsy to-day; has again had severe vomiting. B. regularly open.

4th.—Vomited about 0j. of watery fluid during night.

7th.—Until last evening patient had enjoyed 36 hours freedom from nausea and vomiting; these symptoms returned, however, last night, and there has been some slight sickness this morning. P. 76.

10th.—Was sick again during the night, the vomitted matters containing a small quantity of blood. P. 82.

14th.—Yesterday morning patient coughed up a little blood which was quite bright in colour. Brandy ʒiij.

18th.—No sanguinous excretions yesterday, but again to-day to the extent of about ʒij.

20th.—Vomits bloody mucus daily, usually before breakfast. Eats her chop with relish. B. regular, if anything confined.

24th.—Pt.

27th.—Became worse again two days ago, and yesterday morning fancied she saw rats on her bed; indeed she still imagines she sees them running about; has been very sick this morning, and vomited blood as previously. Brandy ℥vi.

28th.—Patient continues in much the same state. P. 88.

2 p.m. P. 80. Surface cold, pupils small; some squinting still continues, and patient is incoherent and restless as before.

31st.—Continued better till yesterday at 3.30, when faintness came on and the breathing got rapid. This condition lasted about a quarter of an hour, was preceded by faintness and followed by increased talkativeness. During the night patient slept quietly, but at 7 a.m. complained of pain in the head, which was followed by faintness and hurried respiration. Breathing is now 28, P. 88, and very small; has vomited her egg. Tongue pale and bare, but tolerably moist. During examination the breathing became voluminous and rapid. B. regularly open. Strabismus continues at intervals.

Nov. 6th.—Since last report has gradually become less talkative, but still refers to some of her delusions, *e.g.*, that she has received presents from royalty, &c. Appetite has improved; there is still some squinting at times, but not so much. B. regular, no vomiting for the last few days. P. 80; R. 26.

15th.—Went on well from last report up to November 13th, when she complained of stiffness in all her joints, and began to squint again. Yesterday morning the catamenia appeared and patient was quite rational till 11 o'clock, but refused her food and afterwards became talkative and incoherent. For the last week she has had profuse discharge from the vagina. Last evening patient was quieter, but this morning she again became talkative and moreover *discontented*. P. 72, pupils contracted, some internal strabismus, says she wants to leave and refuses to put out her tongue; on the whole has much the same delirium as before, but is unusually ill-natured. Has 6 oz. brandy daily and takes her food well. B. regular.

Nov. 26th.—P. 80, R. 30 to 36, very irregular as regards extent, modus altered, inspiration and expiration equal with much upper sternal movement. Vomits considerably, vomited matter not tenacious, but occasionally streaked with blood; yesterday morning blood alone was brought up. T. natural, slight internal strabismus still remains, pupils slightly but equally contracted, no wandering, and patient takes her food pretty well.

Dec. 2nd.—P. 88, R. 26, very shallow; B. not open for two or three days. Vomited as usual last night and again after breakfast this morning, but not after dinner. Matters vomited abundant and like coffee grounds, not bloody. Brandy ℥ IV. Rept. Pil. podophyl.

Dec. 9th.—During the past week there has been a little wandering and patient has complained of sore throat. It is noticeable that there are now some pale hairs among the black ones. There is a laryngeal tenderness and no tonsillitis. Complains of increased feebleness and sacral pain. Catamenia did not appear at their proper time (viz., a week ago) and patient suffers from leucorrhœa.

January 7th, 1868.—10 a.m. Patient usually vomits once or twice a day, but the amount as well as the frequency varies greatly. B. somewhat confined. Tongue clear, appetite tolerably good. Considerable prostration is complained of, but there is no faintness now. P. 88, R. 36, T. 96. Urine rather thick, slightly opaline after boiling, and is not entirely cleared by NO_3H. Since last evening 7 o'clock 26 oz. have been passed.

On this day I carefully examined the patient, and arranged for the collection and transmission of the specimen of urine, which in the following record are numbered from 1 to 72.

1.—Jan. 8th, 1868.—From 10 a.m. yesterday till 10 a.m. to-day the bowels have not acted, and 21 oz. of urine have been passed, sp. gr. 1,015, strongly acid in reaction, and somewhat cloudy in appearance, which latter character is not entirely removed by heat and HNO_3. On microscopical examination a few

scales of epithelium from the urinary passages were observed, together with numerous multinuclear cells possessing the physical characters of pus.

Pulse 84. Resp. 40. Temp. 96·6. Respirations are somewhat irregular, and patient complains of much shortness of breath, but there has been no return of the vomiting since yesterday's report.

2.—Jan. 9th, 1868.—Was very faint at times yesterday and vomited frequently. Feels somewhat better this morning but still complains of shortness of breath. B. have acted once since last report, motion natural. Breath rather offensive. Urine acid, sp. gr. 1,019, still somewhat thick and cloudy, an appearance which is not entirely removed by heat and HNO. 33 oz. have been passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88. R. 36-40. T. 98·2.

3.—Jan. 10th, 1868.—Did not sleep well during the night, but breath is not so short, and patient feels altogether better. The B. have not acted, nor has there been any vomiting since last report.

6.—Jan. 13th, 1868.—Slept well, and feels somewhat stronger this morning. Breath not quite so short, extremities rather cold, no return of vomiting. B. have not acted since last report. Urine acid, still cloudy in appearance, and not entirely cleared by heat and HNO. sp. gr. 1,020; 24 oz. passed from 10 a.m yesterday till 10 a.m. to-day. P. 84. R. 40–44. Temp. 97·2.

8.—Jan. 15th, 1868.—Slept well and feels better to-day; some vomiting after supper last evening, and again after breakfast this morning. B. open last night, motion hard and mixed with a small quantity of blood. Urine unaltered in character, acid, sp. gr. 1,017, cleared by heat and HNO_3; 26 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 92. R. 36–40. T. 98.

9.—Jan. 16th, 1868.—Slept badly, owing (she says) to shortness of breath. Vomited a little last evening. B. have not acted since last report. Complains of frontal headache with pains in limbs. Some nausea after breakfast this morning, but no vomiting, faintness, or vertigo. Urine acid, sp. gr. 1,021, still cloudy in appearance, and slightly opaline after heat and HNO_3; 22 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88. R 44–48. Temp. 97·4.

10.—Jan. 17th, 1868.—Slept well, vomited a little last evening and was very short of breath, but feels much better this morning. B. open yesterday, and motion contained a small quantity of blood. Urine acid, sp. gr. 1,020, cleared by heat and HNO_3; 21 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. Examined microscopically it is found to contain a number of the same kind of puriform bodies noticed on the last occasion, together with epithelial cells of almost every size and shape; nothing at all resembling a renal cast was observed. P. 84; R. 36; T. 97·4.

15.—Jan. 22nd, 1868.—Did not sleep well as limbs appear to be more painful during the night. No return of vomiting, and patient says she feels much better this morning. B. have acted once since last report, and a good deal of blood was passed with the motion. Patient generally complains of headache and vertigo towards evening. Urine still cloudy, acid, sp. gr. 1,017. Opalescence slightly if at all affected by boiling, and not wholly removed by the subsequent addition of nitric acid; 24 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88; R. 40; temp. 98·6.

16.—Jan. 23rd.—Slept well and is quite free from pain in limbs or elsewhere this morning; no return of vomiting; B. have not acted since last report. Urine acid, sp. gr. 1,020; general appearance as before, but cleared by heat and HNO_3; 27 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 84; R. 32, more regular; temp. 98·4.

22.—Jan. 29th.—Slept well; no return of vomiting, vertigo, or faintness, though still complaining of pain in limbs, especially at night. B. acted last evening; motion natural, and free from blood. Urine acid, sp. gr. 1,020; somewhat opalescent after heat and HNO_3; 33 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88; R. 32–36; temp. 98.

23.—Jan. 30th.—Slept well; no return of sickness, vertigo, or faintness; B. have not acted since last report; patient says she feels better, being free from headache, though still complaining of pains in limbs. Urine

acid; sp. gr. 1,015, cleared by heat and H NO_3; 16 oz. passed during the 24 hours ending 10 a.m. this morning. P. 80; R. 32; temp. 98.

24.—Jan. 31st.—Did not rest so well last night, owing to pains in limbs and pricking sensation at præcordia, which still continues; no return of vomiting, vertigo, or faintness. B. open this morning, and some blood was passed with the motion. Urine acid, sp. gr., 1,020; some cloudiness after heat and H NO_3; 28 oz. have been passed from 10 a.m. yesterday till 10 a.m. to-day. Hands are not so cold as usual; tongue clean; appetite tolerably good. P. 92; R. 36–40; T. 98·4.

29.—Feb. 5th.—Did not sleep so well, owing to pain in left leg and ankle, no sickness, but patient says she felt faint and giddy last evening, with increased shortness of breath, which lasted the greater part of the night. B. open this morning, and a small quantity of blood was passed with motion. 25 oz. of urine have been passed during the 24 hours ending 10 a.m. to-day. P. 88. R. 48. Temp. 97·4.

30.—Feb. 6th.—Slept well, no sickness, faintness, &c., but still complains of constant pain in limbs, especially left leg and ankle. B. open this morning, motion slightly tinged with blood. Urine acid, sp. gr. 1,020. 26 oz. passed during the 24 hours ending 10 a.m. to-day. P. 80. R. 36. T. 96·2.

31.—Feb. 7th.—Slept tolerably well, and has had no return of sickness or vertigo, but felt a little faint last evening, pains in limbs still continue. B. acted this morning, and motion is slightly intermixed with blood. Urine acid, sp. gr. 1,013, tolerably clear after heat and H NO_3; 16 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 82. R. 28-32. Temp. 98·4.

32.—Feb. 8th.—Did not sleep quite so well, but complains chiefly of pain in limbs. B. open this morning, and motion mixed with blood. Urine acid, sp. gr. 1,019, quite clear after heat and H NO_3; 27 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 84. R. 40. Temp. 97.

33.—Feb. 9th.—Slept tolerably well, still complaining of pain in limbs, especially legs and ankles, which are considerably swollen, but do not "pit on pressure." B. not open since yesterday morning. Urine clear after heat and H NO_3; sp. gr. 1,020, acid, only 7 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 80. R. 32. T. 97·2.

38.—Feb. 14th.—Did not sleep quite so well, but says she feels better this morning. B. open last evening. Motion mixed with blood; no vertigo or faintness, but patient vomited once yesterday. Urine acid, sp. gr. 1,012 cleared by heat and H NO_3; 17 oz. passed during 24 hours ending 10 a.m. to-day. P. 88, R. 36–40, Temp. 97·6.

39.—Feb. 15th.—Slept well; no return of vomiting, vertigo, or faintness. Still complains of pain at back of neck and in legs, ankles remain swollen. B. not open since last report; *patient appears to be less discoloured than she was some few weeks back.* Urine acid, sp. gr. 1,021, clear after heat and H NO_3; 12 oz. passed. P. 80, R. 32, T. 97.

40.—Feb. 16th.—Feels much better; had a good night's sleep; was faint for about an hour yesterday afternoon; no vomiting or headache; legs and ankles still swollen and painful. B. open this morning; no blood in motion. Urine acid, sp. gr. 1,020, no albumen, 24 oz. passed. P. 88, R. 40, T. 98.

41.—Feb. 17th.—Vomited several times last evening and once again this morning, but slept fairly and does not feel any the worse. B. not open since last report; no vertigo or faintness. Urine acid, 1,024, clear after heat and H NO_3; 12 oz. passed from 10 a.m. yesterday till 10 a.m. to-day; P. 80, R. 36, T. 96·8.

42.—Feb. 18th.—Did not sleep during the night; vomited two or three times this morning, and complains of severe pain in limbs and at back of neck. B. not open since last report. Urine acid, sp. gr. 1,024, clear after heat and H NO_3; 14 oz. passed. P. 88, R. 44, Temp. 96.

Feb. 23rd.—Yesterday evening commenced vomiting, which continued during night. Bowels open three times after aperient. No urine saved. Very little sleep during night.

47.—Feb. 24th.—Vomiting continues; vomited matters consist principally of undigested food; no blood. Very restless night; no sleep. Tongue clean, red, moist. Complains of headache, thirst, and pains in limbs. Pulse 80, small, irregular. Resp. 52. Temp. 99. Urine, 30 oz. passed. Sp. gr. 1,017. Acid clear by heat and nitric acid.

48.—Feb. 25th. Urine, 16 oz. passed, sp. gr. 1,021, acid; no albumen.

49.—Feb. 26th.—Has not been sick since yesterday; complains of giddiness; no sleep for several nights; pains in limbs better; no appetite; tongue clean and moist; bowels open yesterday morning; less thirst; P. 88, very small and irregular; R. 30, easy. Urine, 8 oz. passed; sp. gr. 1,025; acid; cleared by heat and $H\,NO_3$. Temperature not taken.

50.—Feb. 27th.—Urine, 18 oz. passed; acid; sp. gr. 1,016; clear after heat and nitric acid.

51.—Feb. 28th.—No vomiting since last report; sleeps fairly; still complains of pains in limbs, and also along spines of cervical vertebræ, where is slight tenderness on pressure; no giddiness for two days; bowels open daily; no thirst; tongue clean and moist; pulse 86, small and irregular; R. easy, 30. Urine, sp. gr. 1,022; acid; 15 oz. passed; clear after heat and nitric acid.

58.—March 6th.—Feels better; pains in cervical spines and limbs continue, the same as at last report; no vomiting or giddiness; *complexion appears somewhat lighter in colour than it was several weeks ago;* appetite good; bowels open daily; tongue clean; P. 88; R. 26. Urine, 15 oz. passed, acid; sp. gr. 1,020; clear after heat and nitric acid.

March 9th.—Sleeps well; pains in neck very severe, and in limbs much the same as at last report; no giddiness or vomiting; feels stronger; P. 88, small and irregular; R. 20; appetite good.

62, 63.—March 11th, 1868.—Slept well; some little nausea complained of this morning, but no vertigo, headache, or faintness; legs are still swollen and painful to the touch, though neither inflamed nor œdematous; B. open last evening; tongue clean; appetite good. Urine acid; sp. gr. 1,020; clear after heat and $H\,NO_3$; 12 oz. passed during the last 24 hours; P. 96; R. 44. Yesterday 20 oz. of urine were passed, acid, sp. gr. 1020, and no albumen.

64.—March 12th.—Urine acid; sp. gr. 1,020; 14 oz. passed; no albumen.

65.—March 13th.—Patient appears to be improving; skin clear and less discoloured; no return of nausea, vertigo, or faintness, but some pain in legs still complained of; B. open yesterday. Urine acid; sp. gr. 1,015; no albumen; 22 oz. passed. P. 92; R. 36–40.

TOTAL QUANTITY of URINE excreted in 24 Hours.

No. of Specimen.	Date.	Total Quantity of Urine excreted in 24 Hours in Cubic Centimetres.	Remarks.	
1	Jan. 8th	615	Of each specimen 20 CC were taken away for investigating the constituents generally. The remaining main bulk was used for investigating uric acid and urochrome.	Nos. 1 to 6 treated for uric acid with hydrochloric acid.
2	„ 9th	950		
3	„ 10th	863		
4	„ 11th	570		
5	„ 12th	643		
6	„ 13th	690		
7	„ 14th	765		
8	„ 15th	735	5 CC for testing.	Nos. 7 to 12 treated for uric acid with sulphuric acid. Mean of uromelanine 0·0649 per day; uropittine and omicholine 0·0886 grammes per day.
9	„ 16th	610	„ „	
10	„ 17th	605	„ „	
11	„ 18th	760	„ „	
12	„ 19th	327	„ „	

TOTAL QUANTITY of URINE excreted in 24 Hours—*continued.*

No. of Specimen.	Date.	Total Quantity of Urine excreted in 24 Hours in Cubic Centimètres.	Remarks.	
13	Jan. 20th	862	5 CC for testing.	Nos. 13 to 15 treated for uric acid with hydrochloric acid.
14	„ 21st	1,007	„ „	
15	„ 22nd	705	„ „	
16	„ 23rd	832	„ „	Nos. 16 to 65 treated for uric acid with sulphuric acid. Mean of uromelanine in each day, from 13th to 24th, 0·0557 grammes; mean of uropittine and omicholine, 0·0255 grammes.
17	„ 24th	570	„ „	
18	„ 25th	390	„ „	
19	„ 26th	572	„ „	
20	„ 27th	215	„ „	
21	„ 28th	918	„ „	
22	„ 29th	995	„ „	
23	„ 30th	470	„ „	
24	„ 31st	768	„ „	
25	Feb. 1st	705	No further portions were removed for general testing, as no questions were raised by appearances or symptoms.	Sulphuric acid employed for uric acid research, and a new quantity for chemolysis. Found uromelanine, mean per day, 0·0794 grammes; omicholine and uropittine, 0·0362 grammes.
26	„ 2nd	998		
27	„ 3rd	852		
28	„ 4th	845		
29	„ 5th	700		
30	„ 6th	740		
31	„ 7th	456		
32	„ 8th	762		
33	„ 9th	185		
34	„ 10th	483		
35	„ 11th	215		
36	„ 12th	376		
37	„ 13th	308		
38	„ 14th	510		
39	„ 15th	387		
40	„ 16th	652		
41	„ 17th	352		
42	„ 18th	412		
43	„ 19th	460		
44	„ 20th	575		
45	„ 21st	590		
46	„ 22nd	752		Feb. 23rd, no urine saved.
47	„ 24th	865		
48	„ 25th	508		
49	„ 26th	270		
50	„ 27th	530		Acids employed as above. Found uromelanine, mean per day, 0·0682; uropittine and omicholine, 0·0398.
51	„ 28th	455		
52	„ 29th	760		
53	Mar. 1st	527		
54	„ 2nd	722		
55	„ 3rd	405		
56	„ 4th	362		
57	„ 5th	750		
58	„ 6th			
59	„ 7th	238		
60	„ 8th	345		
61	„ 9th	518		
62	„ 10th	320		
63	„ 11th	572		
64	„ 12th	422		
65	„ 13th	590		

Chemical Examination of the Urine.—The filtered urine was concentrated on the steam bath, and mixed with some acid. With the first six specimens, and with Nos. 13, 14, and 15, hydrochloric acid was

Chemical examination of the urine.

employed; to all others sulphuric acid was given. After 24 hours standing a deposit of a reddish brown or violet colour had collected, which was separated by filtration and washed until free from acid. This deposit never showed any appearance of crystals, so that if it contained any uric acid this must have been present in an amorphous state. The precipitate was first extracted with alcohol as long as this agent removed any coloured ingredients; the residue was thus free from hippuric acid and omicholine and uropittine, which, if present, must have been contained in the alcoholic solution. The residue was next extracted with dilute ammonia, in order to remove any uromelanine. Some brown matter was extracted, but found not to be uromelanine. The extract was quite free from uric acid. The residue left undissolved by ammonia was now treated with caustic potash to extract any uric acid. None could ever be obtained by the analysis of the urine of a single day, or of the combined urine of three or six days. The whole of the precipitates obtained from the whole of the urine from 12 entire days had to be united in order to obtain an unequivocal proof of the presence of uric acid; but the quantity which could be precipitated by acetic acid from the potash solution was only just large enough to serve for a microscopical test and a reaction with nitric acid. It was not feasible to weigh what remained as it was so small a quantity.

The urines Nos. 13 to 24 inclusive were treated like the first dozen specimens, the whole of the quantities being always employed. No trace of uric acid was found.

Nos. 25 to 36 similarly treated gave no evidence whatever of the presence of uric acid. Nos. 37 to 48 also contained no trace of uric acid. The ammoniacal and alcoholic extracts were in each case examined for uric acid, but as was to be expected were found quite free from it.

The acid liquid which had been filtered from the precipitate was mixed with sulphuric acid and subjected to distillation in a retort. By chemolysis a considerable precipitate was produced, which was isolated on the filter and washed. It appeared granular, and not resinous or semi-fluid. It was extracted with alcohol, which removed uropittine and omicholine, and left uromelanine behind on the filter. The latter was dried and weighed. The uropittine and omicholine were obtained by evaporation of the alcohol, dried in watch glasses, and weighed together. The quantities of uromelanine and uropittine and omicholine obtained are stated in the following table :—

No. of Urine.	Grammes of			
	Uromelanine.		Uropittine and Omicholine.	
	Total.	Per Day.	Total.	Per Day.
1 to 12 - -	0·7793	0·0649	1·0641	0·0886
13 to 24 - -	0·6685	0·0557	0·3070	0·0255
25 to 36 - -	0·9539	0·0794	0·4346	0·0362
37 to 48 - -	0·8186	0·0682	0·4780	0·0398

Conclusions.

From the above researches the following conclusions may be drawn :—

1. The urine in this case of bronzed skin disease or peculiar degeneration of the supra-renal glands contained during the first 12 days of observation only a minimum of uric acid. 2. During a continuous

period of 36 days the urine contained no uric acid whatever. 3. By chemolysis the urine yielded quantities of uromelanine, which amounted to about one-twelfth part of the quantity obtained from the urine of healthy persons during equal times. 4. The matters soluble in alcohol (omicholine and uropittine) obtained by chemolysis are far below the normal quantities, and do not stand in any uniform ratio to the uromelanine, the first 12 days yielding more matters soluble in alcohol than uromelanine, while the three periods of 12 days each which follow yield only about a third of the weight of the uromelanine in matters soluble in alcohol. If the fact of the irrationality of the quantity of these products should be well established, it would show that uromelanine on the one hand, and uropittine and omicholine on the other, cannot be derived from one and the same substance (urochrome). I hesitate, however, in forming that conclusion, because I suspect that uropittine is capable of transformation into uromelanine, and in that case the apparent irrationality of the results of the first 12 days might disappear on subsequent separate determination of the omicholine and omicholic acid.

General remarks on bronzed skin disease.

The above history of the case leads to some remarkable conclusions, which it is desirable to point out. 1. The brown deposit in the skin is the varying balance of a current account. It may increase or decrease. It decreased in the above case during two distinct periods. 2. The origin of the coloured matter is to be sought in the hematocrystalline, which while in the blood corpuscles undergoes a change unfitting the blood to pass through the capillaries. Hence the many hemorrhages and secretions on the one hand, the swellings and nervous symptoms on the other, and the deposits in the periphery, which become changed mainly under the influence of light. The further analysis of this case, and of similar ones, must be the work of a future time.

IX.—CALCULI ARISING IN THE URINARY BLADDER IN TYPHUS.

The relaxation of the striated muscles which takes place in typhus fever frequently causes, particularly in old persons, great distension of the urinary bladder. This distension is not rarely overlooked, as there is no impediment to the flow of urine. It is also accompanied with involuntary passing of the urine, particularly in young persons. In children I have seen it pass into retention, with deposits forming in the bladder. It is most frequent amongst men in the later periods of life. The retention does not, so long as the urine has the acid concentrated character of the febrile stage, produce any phosphatic deposits; but during the anæmic state of recovery ammoniacal decomposition takes place, mucus is secreted, phosphates are deposited, and calculi are formed, which increase rapidly, and if not removed by operation cause kidney disease and death. The calculi under consideration, four in number, came from such a case. They had the size of walnuts, were white, hard, and contained each a cavity of the size of a pea in their interior. The cavities were empty when observed, which was after the calculi had been dry for some time. There is little doubt that the contents of these cavities were originally mucus, upon which the outer matter had been deposited. The mucus drying up left the cavities.

Analysis of one of the calculi.

Analysis of one of the Calculi.—The finely powdered stone was almost entirely soluble in dilute hydrochloric acid, the solution being only slightly opalescent. The filtered solution gave on addition of ammonia a precipitate easily soluble in dilute acetic acid. On addition of oxalate of ammonium a minute precipitate of oxalate of calcium was observed. On adding caustic potash to the powdered stone ammonia

was evolved. The calculus therefore consisted mainly of phosphate of magnesium and ammonium, with traces of phosphate of calcium and ammonia. There was no uric acid and no oxalate of calcium.

The quantitative analysis yielded some curious results. 1·0195 grammes during drying in the water-bath at 100 lost 0·4120 grammes, or 40·41 per cent. From the residue there were obtained by oxalate of ammonium, &c., 0·03 grammes calcium carbonate, corresponding to 0·031 grammes of phosphate of calcium ($3\,Ca\,P_2\,O_8$), or 3·04 per cent. Further, 0·4482 grammes of pyrophosphate of magnesium ($2\,Mg\,P_2O_7$), corresponding to 0·9892 ammonio-phosphate ($Mg,\ NH_4\ PO_4,\ 6\ H_2O$) or 97·02 per cent. of the original calculus.

$3\,Ca\,P_2\,O_8$ - - - - -	3·04
$Mg,\ NH_4\ PO_4\ 6\ H\,O$ - - -	97·02
	100·06

As the 1·0195 grammes of calculus lost 0·4120 in weight during drying, while, if the loss had been that of five-sixths of the water contained in the triple phosphate, it should have amounted to 0·3633 only, there was an excess of 0·0487 lost. The question now arose whether this was water or ammonia.

1·2259 grammes of calculus powder were heated in the water-stove. After having been in it for about half an hour the powder was taken out, and a glass rod moistened with hydrochloric acid was brought near to it. Thick vapours of chloride of ammonium were immediately formed, A piece of blue litmus paper, reddened by vapours of hydrochloric acid, was turned blue again while being held over the powder. The powder therefore lost both water and ammonia during drying at 100°, and, as was ascertained by five weighings, the more the longer the drying was continued.

A quantity of pure phosphate of ammonium and magnesium was now prepared, and when air-dry was brought into the vacuum over sulphuric acid. It was kept there for six weeks, and during that time weighed eight times, at nearly equal intervals. Each time it was found to have lost five or six centigrammes in weight. It is therefore clear that the crystallized triple-phosphate, when brought air-dry or nearly so into a vacuum, loses, besides adherent moisture, either water of crystallization, or ammonia, or both.

The calculus thus contained in 100 parts—

Water, and little ammonia given off at 100° -	40·41
Water and ammonia given off by red heat -	12·59
Pyrophosphate of magnesium - - -	43·96
Phosphate of calcium - - -	3·04
	100·00

X.—ON ALCOHOL, IN RELATION TO THE CHEMISTRY OF THE HUMAN BODY.

Alcohol.

Alcohol is the principal produce of the fermentation of the juice of the grape, and no doubt it was by the natural transformation of the juice of the grape that alcohol was first discovered. Other fruits containing sugar also yield alcohol by the natural decomposition which they undergo the moment they are taken from the tree and crushed. Alcohol, then, is the active ingredient of all vinous or spirituous liquids. It is derived from a kind of sugar which we term "fermentescible sugar,"

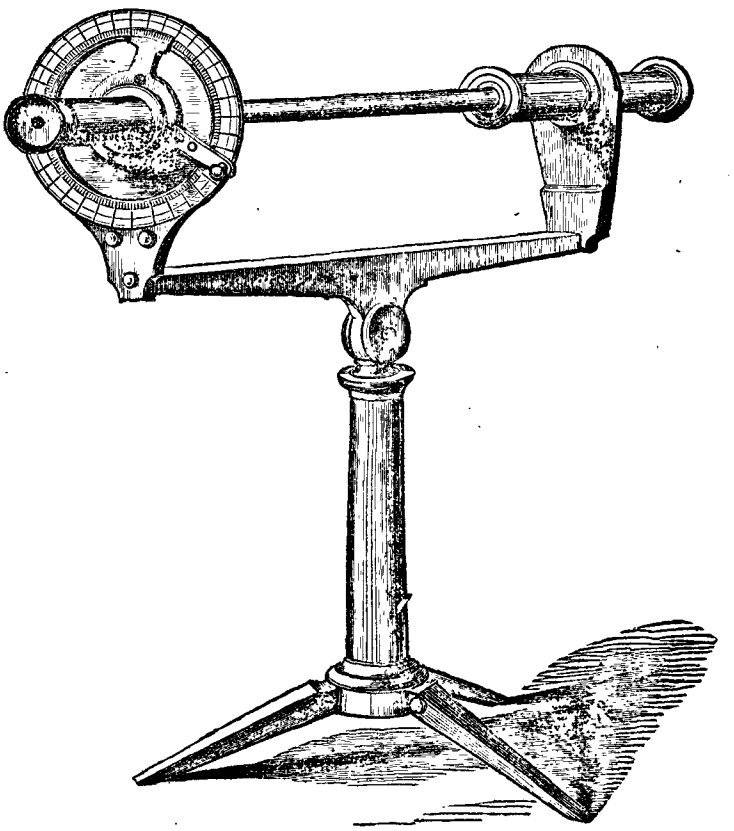
and about which the learned of the various nations are not yet quite agreed. This sugar is most probably a mixture in atomic proportions of one kind of sugar which turns to the right the plane of polarization, and another kind which turns the plane of polarization to the left.

Invert sugar.

The sugar which turns the plane of polarization to the right is called dextrose, or starch sugar, and its formula is $C_6 H_{12} O$. In some of its crystallized forms it possesses water of crystallization, and when it is crystallized from absolute alcohol it falls down in needles, which are anhydrous; but when it is crystallized from watery spirit solution it is deposited in cauliflower-shaped masses which are hydrated. The second kind of sugar which is contained in fruit is that which is called levulose, (from *lævus*, left,) or left-turning sugar. The formula is $C_6 H_{12} O_6$. Some chemists assume a difference, inasmuch as they say that one is a polymer of the other, but that is not well established.

Polarization.

The reader may perhaps ask, what is the right-turning and what is the left-turning property? Practically and shortly it amounts to this, that when you have a polarizing apparatus of which the index stands at zero, while nothing or ordinary water is in it, then when you put a solution of dextrose into the tube the index has to be turned to the right



Chromatic Polarimeter.

in order that the light may fall through the apparatus in the same manner as when it was empty; or, in the case of levulose, the index has

to be turned to the left in order that you may look through the fluid as you do for the zero point.

The polarization of bodies changes very much according to the heat which they undergo. If dextrose is not heated it turns to about 116° of the circle, but when it is boiled once, or heated to near the boiling point, it only turns to 54°. This is the distinguishing property of of dextrose. Levulose, which turns to the left, does not show this change by heating. Now when these two varieties of sugar are present in wine, or in any artificial produce such as that which can be made by sulphuric acid from starch or cane sugar, the optical effect of the one hides the optical effect of the other if they are present in equal atomic proportions. If they are not present in equal atomic proportions then the one hides only a certain quantity of the other, and the optical effect is that only a portion of that which is in excess is perceived. For this reason, that the levulose reverts, as it were, the polarization of the dextrose, the mixture has been called "invert sugar," or "sucre interverti," which is the French name.

Immediate production of invert sugar.

We can in one instant produce the invert sugar by a very interesting experiment. This has been known since the year 1812, but it has been completely forgotten in all the discussions which have taken place as to the nature of yeast. We will take two parts of common white sugar, or cane sugar of the formula $C_{12}H_{22}O_{11}$, and mix them with one part of dry solid, so-called German yeast. The quantity of water which may be present in this yeast must be very small. It is hard, well-pressed yeast, and it does not even wet the paper in which it is contained. If we press the paper, and however much we press it, there is no mark of water upon it. We take a quantity of this, which we have detached from the lump, and weigh it off. We mix with that the double quantity of sugar by stirring them in a mortar. As if by magic the sugar is transformed into a syrup, the transformation of cane sugar into invert sugar is completed. I keep in the laboratory a quantity which I have made some time ago, and it is still a flowing liquid mass, a syrup. Now, when this is allowed to stand for only a very short time the proof that it is inverted sugar can be easily afforded. Cane sugar when treated with Fehling's solution does not give the reaction which consists in the reduction of the oxyide of copper contained in that solution. We will take a little of the cane sugar, and put it into this tube with a little of Fehling's solution. This consists of sulphate of copper to which some tartaric acid has been added, and the mixture has afterwards been made alkaline by the addition of an excess of caustic potash. Now when we heat this we obtain no reduction of the oxide of copper. The oxide of copper remains perfectly clear in the alkaline blue solution, but the moment we take a little of this inverted sugar, produced by the effect of yeast upon cane sugar, we obtain the reduction of the oxide of copper, and it is deposited in the form of yellow hydrated suboxide of copper, a sufficient proof that the cane sugar has actually been transformed into the inverted sugar.

Theory of yeast.

This is of the utmost importance, as directing the view which we may take of the nature of yeast. I consider this a fundamental experiment, which speaks against the assumption that the action of yeast in producing fermentation is due to organic life action. I believe it entirely upsets that idea, inasmuch as the transformation is instantaneous, and partakes of the nature of those actions which in chemistry we are in the habit of calling "contact actions." Moreover, it is not necessary, in order to produce the transformation, that we should use the yeast itself. We can take a watery extract of yeast, and this

extract of yeast will have the same effect, and almost in the same manner.

It is interesting to know that that kind of sugar which is excreted from the body in such large quantities in a particular disease is not this inverted sugar. Diabetic sugar consists mainly of grape or dextrose sugar. At present it is almost impossible to get any levulose at all out of diabetic urine, because it does not crystallize. It is a syrup, and by no means in our power can we make it solid, but it remains a liquid like glycerine. During the process of fermentation, on the other hand, we perceive the quantity of left-turning sugar to prevail over the other. In the beginning of fermentation there are two dextrose upon one levulose, and at the end of fermentation there are two levulose upon one dextrose. In the various stages intermediate between the beginning and the end of fermentation these proportions vary.

Diabetic sugar is dextrose.

Change of proportions of sugar during fermentation.

We are obliged to omit the consideration of other properties of these various sugars in order to come to their transformation. When the mixture of dextrose and levulose are subject to the action of yeast for any length of time, then a transformation takes place, which consists in the production of alcohol and other matters. Hitherto it was believed that sugar was directly transformed into nothing but alcohol, and carbonic acid :—

$$\mathfrak{C}_6\,H_{12}\,\mathfrak{O}_6 = 2\,(\mathfrak{C}_2\,H_6\,\mathfrak{O}) + 2\,(\mathfrak{C}\mathfrak{O}_2)$$

This was believed to be the formula of the breaking up of the whole sugar, but we have found now that it is very different, and that of 100 parts of sugar only 94 pass into carbonic acid and alcohol, and that

3·5	are transformed into	glycerine,
0·5	„	succinic acid,
1·5	„	cellulose,
·5	„	carbonic acid,

in connexion with the glycerine and succinic acid. We have here, therefore, an important modification of our former ideas on the subject of fermentation.

Action of yeast.

We will for an instant see what is the action of yeast under these circumstances. We have seen that in the transformation of cane sugar it is instantaneous, and that the presence of the yeast-cell is not necessary, but that an extract, something coming from the yeast-cell, will do it. It is similar in the case of the transformation of sugar into alcohol. Here, however, the presence of the yeast cell is certainly necessary, but nevertheless the yeast-cell itself is not that which causes the transformation. It is something which comes from the yeast-cell which causes the transformation. The yeast-cell is supposed to be a kind of fungus the individuals of which multiply by growth.

Yeast cells.

Some suppose that these cells absorb the sugar, and then breaks it up in its interior and gives out alcohol and water. But this is a process which we cannot for an instant assume, because there is no benefit to the yeast done in that, and moreover the action is too rapid. It does not stand in any proportion to the amount of matter which any plant, or any living body, can consume in any given time, and any quantity of yeast, even a small quantity, may transform so vast an amount of sugar, that it is inconceivable that that plant should have used this amount of sugar as physiological food. Be that how it may, the result of this process is the production of alcohol.

Various sugar-like substances yield alcohol.

Other sugars, mannite, dulcite, sorbine, lactose, including glycerine, cane sugar, starch, gum, and the dextrine which is found in the liver, or so-called hepatine, yield alcohol under certain influences, *e.g.*, water,

chalk, and cheese, at a temperature not exceeding 60°. Alcohol, therefore, is by no means the exclusive product of levulose and dextrose, but other matters also produce it in small quantities. There is also another substance acetylene, $C_2 H_4$, which may be dissolved in sulphuric acid, and if this is afterwards mixed with water and distilled alcohol passes over. This has given rise to the proposition, that for the future a portion of the alcohol consumed by the public should be made from coal gas, which contains a small quantity of this gas. Should that proposition be realised the public may be supplied with light and with spirit from the same source.

Alcohol, description of.

Alcohol, in its isolated and distinct form, was discovered about the 12th century, and it was named by the Arabian physician Geber alcohol, that is, spirit. No doubt alcohol was known to the ancients, and it is not to be supposed that the famous Pramnic wine, of which Homer speaks, and which could be taken diluted with 20 measures of water, and yet make a man drunk, was anything short of 60 over-proof spirit. But the chemistry of alcohol has only in this century been more clearly evolved. We have learned that alcohol is a hydrated oxide of a radical which we call ethyl, and in that capacity is the representative of a series of bodies which are of the utmost importance in organic and theoretical chemistry, namely, of the alcohols. Ethylic alcohol may be written thus :—

$$\left.\begin{matrix} C_2 H_5 \\ H \end{matrix}\right\} O$$

Absolute alcohol is a liquid. It is colourless, it has an agreeable flavour, and burns when fire is set to it. It has also a burning taste, but the taste of pure alcohol is very agreeable indeed, and this is quite the reverse of what people ordinarily say, namely, that distilled alcohol has a nasty taste. It has a nasty taste, as ordinarily obtained, but this is due to the circumstance that certain products of decomposition are mixed with it, which, however, can be entirely removed, as Döbereiner has shown, by passing the distilled alcohol 50 times over animal charcoal. When it passes 50 times it is absolutely pure, and has the chemical properties and taste described.

Its specific gravity at zero is ·8095. At 14, however, which is the ordinary temperature, it is ·7982. It boils at 78 of the centigrade thermometer, under the pressure of 760 millimetres of the barometer. Even at the strongest cold, a temperature of — 100, it is only transformed into a thick fluid, but it is not solidified at any temperature or by any means. It can be burnt in a spirit lamp, and there comes little or no light from it. Alcohol attracts the moisture very rapidly, so quickly so that it may be compared to sulphuric acid in its power of so doing. With water it becomes warm and then contracts; 49·8 volumes of water, and 53·7 volumes of alcohol, which if they mixed without contraction would give 103·5, will contract so as to form 100.

Brandy obtained by distillation of wine.

When wine is distilled at a moderate heat a mixture of alcohol and water passes over which has about the foregoing composition, and this mixture is called brandy, but, whereas the art of distilling has become very much greater of late years, this brandy is not manufactured any more. In fact, it is an important element in trade that the articles to be sold and transported should be as concentrated as possible. Why should the brandy merchant in London carry three barrels from Montpelier to London when he can carry the same value of alcohol in two? Consequently the distiller transforms all his brandy into the strongest alcohol, namely, 60° over proof, and he does this by means of a particularly

adapted still. This mode is now generally adopted by the distillers of alcohol in all the great brandy-producing districts of France, Montpelier and Cognac in particular. There were last year 400,000 hogsheads of strong alcohol produced there, but the old method of producing brandy is almost out of use. The new method, then, gives a very strong alcohol, but it still contains some water. The chemist, therefore, in order to obtain alcohol pure, avails himself of various processes for the purpose of extracting it. The trade, who do it on a large scale, use burnt lime. Burnt lime is put into large vats, the alcohol is poured over, and the pure alcohol comes off, the water being retained in the lime. In the laboratory, however, we do it on a smaller scale, and use as a dehydrating agent the sulphate of copper. This salt is crystallised with a certain amount of water, and then is blue, but when we heat it it loses the water and becomes white. By shaking a sufficient quantity of this with strong alcohol the latter is made quite dry, and the copper salt becomes again blue or hydrated. We use this test also for the purpose of ascertaining whether the alcohol which we have been producing is anhydrous or not. If it be anhydrous the sulphate of copper will remain white; if it contains water the sulphate of copper will become blue. By means of large quantities of dehydrated sulphate of copper great quantities of dehydrated alcohol may be made.

Modes of obtaining concentrated and anhydrous alcohol.

Method of determining the Quantity of Alcohol in Fluids.—When we have a mixture of alcohol and water we obtain the specific gravity by means of an instrument called the hydrometer. In water only this hydrometer would stand at 1,000, but the lighter the fluid becomes the deeper it would sink, and in absolute alcohol it would sink to 798·2. If we have a mixture of alcohol and water, and we will determine the quantity of alcohol contained in it by the use of this hydrometer, we read the specific gravity, and from certain tables which we have we can tell the quantity per cent. by weight of alcohol contained in that fluid.

Method of determining quantity of alcohol in fluids.

Now this is the scientific method of doing it. But the law of England in this respect is different, and is distinguished from the practice of all continental nations in this, that it assumes a different standard, namely, a standard which is called "proof-spirit." By an Act of Parliament which was passed in the 56th year of the reign of George III. chapter 160, in the year 1816, it is enacted that the standard of all spirits upon which the excise shall levy taxes is to be a mixture of alcohol and water which shall weigh 12, while the same volume of distilled water shall weigh 13, all at a temperature of 51° Fahr.; or in the words of the Act: "And whereas since the passing of the said Acts an hydrometer "called Sykes's hydrometer has with great care been completed, and "has, by proper experiments made for that purpose, been ascertained "to denote as proof-spirit that which at the temperature of 51 degrees "by Fahrenheit's thermometer weighs exactly $\frac{12}{13}$ parts of an equal "measure of distilled water." How has the Legislature, or the traditions of this country, fallen upon this curious standard? This is a very singular story to tell. Before science had anything to do with buying and selling, it was usual to take a saucer and put a little gunpowder in it, and then pour a little of the spirit which was to be tested over it. Then the spirit was set fire to and burned, and at the conclusion of the combustion it was necessary that the gunpowder should also take fire. The spirit was called "proof" if it was sufficiently concentrated to cause the gunpowder to burn; for if the spirit contained so much water that at the end of the combustion the gunpowder was wet, then of course it did not burn. This, then, is the derivation of "proof-spirit," and according to this standard nearly all the spirit used in this

Proof-spirit.

History of "proof."

country is now bought and sold. Doubtless we shall in time conform to the method of other countries, so that also here a spirit shall be bought and sold according to its per-centage by weight in volume.

Discussion of medicinal properties of alcohol.

I have given a very explicit description of this particular substance, because I wish to go to the root of a certain question which has for a long time agitated the learned, and particularly physicians. Some years ago there was a great discussion on the question: Is alcohol food or physic? The great wonder was that while hundreds of men talked about it, none ever dreamed of setting to work to ascertain the solution of the question, until it struck three French learned men, namely, Lallemand, Perrin, and Duroy (the first one the late surgeon who died in the Mexican expedition), that they would investigate the question whether alcohol when it was taken into the body was actually burned up, as Liebig had stated, or whether it was given out again unchanged. They caused a man who could consume a great quantity of alcohol to drink a certain quantity, and then they collected his urine, distilled it over, and to their very great surprise they found that the alcohol reappeared in the urine. They could burn it, they could show its presence, and straightway they ran to the conclusion that alcohol is not food. They said, "Alcohol is taken "into the body and goes again out of the body; it is true we have only "found a small quantity in the urine, but we must imagine that the lungs, "the skin, and the fæces admit of a very much greater portion being "exhaled, and therefore the fact that we have not found the whole does "not matter." In fact the question of quantity hardly entered their minds. They had found alcohol, and they straightway went to the conclusion that the alcohol is entirely secreted, and is a stimulant and not a food. About two years ago this question engaged my attention, and I availed myself of an opportunity which I had of making an experiment on a large scale. 44 bottles of wine were drunk by 33 men during six hours of athletic sports, and their urine passed during six hours was collected under my observation for analysis. It was then subjected to 24 distillations, whereby with the aid of dehydration by copper sulphate a small quantity of alcohol was obtained weighing ten grammes. Then arose the remarkable question: In what proportion does the alcohol recovered stand to the alcohol consumed? and there we must again be guided by chemical analysis. The 44 bottles which were drunk by the 33 men contained 4,000 grammes of absolute alcohol, and there were, after dehydration, 10 grammes of alcohol obtained, the rest having been burned up in the system. Supposing that 10 grammes more passed out through the breath, the pores of the skin, &c., it would only give five grammes out of every thousand, or ½ per cent., as the quantity which was left unused by the system. We have, therefore, here a direct proof that out of the whole quantity of alcohol drank only a quarter per cent. was excreted by the kidneys.

French experiments.

New experiments.

Subsequently going further, and in conjunction with my friend, Dr. Dupré, lecturer on chemistry to the Westminster Hospital, I made a great many smaller experiments in order to prove that the above was not an exceptional fact but the actual and invariable rule.

Dr. A. Dupré's experiments.

Experiment with Bordeaux Wine upon Six Men.—Six young men consumed 255 fluid ounces of red Bordeaux wine, containing 11,018 grains of absolute alcohol. The observation commenced at 1 o'clock p.m., and within an hour and a half, during which the men were engaged in sports and gymnastic exercises, four-fifths of the wine had been taken. All were more or less affected, two very strongly, which had not been the case in the previous experiment. Their urine was

collected till 5 p.m., and found to amount to 216 fluid ounces. It was four times distilled with the usual precautions. The final distillate amounted to 3 oz. The specific gravity of this distillate at 15·5° C. was 989·16, and therefore contained 6·32 per cent. of absolute alcohol by weight. A portion of the same distillate, when oxydised by potassium dichromate and sulphuric acid, gave an amount of acetic acid which was equivalent to six per cent. alcohol. Another portion of the distillate tested in Geissler's vaporimeter gave an indication leading to 7·3 per cent. alcohol, which would indicate that there was a small quantity of a substance more volatile than alcohol contained in the mixture.

Absolute alcohol taken in 255 oz. of wine = 11,088 grains.
" " obtained from 216 oz. of urine = 91·03.

Therefore of every 121·8 grains of alcohol taken 1 grain was reobtained from the urine. Of 100 absolute alcohol only 0·82, or a little more than four-fifths per cent. was recovered.

Comparison of the two foregoing experiments.

In my experiment on the large scale we could not be sure whether some very small quantity of the wine may not have been accidentally lost. But the foregoing experiment was minutely accurate in this respect. The quicker consumption in the second case may have made a difference, for less alcohol passes into the urine in proportion as we drink it in smaller quantities and at longer intervals; and I believe from further experiments that there is a limit, and that if we do not pass that limit no alcohol whatsoever, excepting the merest infinitesimal portion, passes into the urine, and that is 8, or 10, or 12 ounces of wine, namely, just that quantity which a reasonable man might drink with his dinner.

Mode of isolating alcohol from organic fluids.

Before continuing the account of the experiments on alcohol, I shall proceed to consider the manner in which it is isolated from organic liquids.

We will, as a pattern-fluid, take urine, which we have examined most frequently; but if it were necessary to analyse any other liquid of the human body, lymph, or any serous liquids, or watery extracts from any organ, in case we wanted to investigate the distribution of alcohol in the tissues, we would apply the same process to those watery extracts.

Distillation with tannic acid.

In the first instance we put them into a retort, and add a small quantity of tannic acid. This tannic acid is very necessary in order to prevent frothing. If we were to boil urine merely by itself without adding tannic acid, we would probably have bumping and frothing, and a small quantity of urine would pass over into the condenser, and we would lose our distillation. Having thus distilled the fluid once by itself, we proceed to re-distil it in order to remove from it any acid that may be present. We add a small quantity of caustic potash to the liquid, and after having given time for the reaction we proceed to distil it again. The effect of that process is that all the volatile acids are retained, while nothing but the alcohol and the ether present passes over. We have now already reduced the quantity of the fluid very much, and subject it now to a third distillation, this time with sulphuric acid, so that any volatile alkalies which may have been driven out in the first instance may not pass over but be retained. The third distillate, then, which is mostly only about one-eighth part of the original quantity, contains all the alcohol, no volatile acids, no volatile alkalies, and this produces a liquid which we now use for the test to be described.

Distillation with caustic alkali.

Distillation with sulphuric acid.

Chromic acid test for alcohol.

Alcohol when it is brought in contact with free chromic acid is so

much heated that it takes fire, and a kind of explosion takes place; but when we take a dilute solution of chromic acid, such as is produced by mixing dichromate of potash with sulphuric acid, we only obtain a slight reduction, and that is indicated by a transformation of the red colour of our test into a green colour. The sulphate of oxide of chromium is formed instead of the acid. We generally take one part of the dichromate to 300 of the sulphuric acid. We must take care to mix the distillate with two parts of sulphuric acid in the concentrated state, so that for the test we have considerably concentrated liquids. If we have not concentrated liquids we are liable to miss our test. If we pour a little of this into the mixture so that it sinks to the bottom, we perceive that where the one fluid touches the other there is a deep green colour, and then a ring of lighter green; and even if we have as little as one-fourth or one-tenth of a grain of alcohol in half an ounce of water, it will yet, by means of this test, be indicated. The test, therefore, is a very delicate one. Of course it is necessary that we should, before applying this test, have taken the precaution of distilling the fluid three times, as above detailed, otherwise the test will be fallacious on account of the organic matters not being alcohol decomposing the chromic acid in the same manner as alcohol.

Particulars of proceeding applied to urine.

The particulars of proceeding for determining alcohol in urine are the following: Test liquid, one part of dichromate of potash dissolved in 300 parts of sulphuric acid, that is, the solution which has already been described. If we make the reaction very nicely we can even discover the one-hundredth part of a grain of alcohol, but not in the quantity of half an ounce of fluid. Applied to the urine we need not generally take more than two ounces of urine. It is necessary that we should save labour as much as possible in these operations which have, in long researches, to be often repeated, and therefore it is well to know that two ounces will be a sufficient quantity to treat. Of that we distil off one-third under the precaution which I have mentioned as to tannic acid. Then of the distillate we draw off again one-third, so that we have one-sixth of the original; and of that again one-third, so that we have one-ninth of the original. During the operation of distillation, if we want to make quantitative researches it is necessary that we should close the whole of our apparatus so as to be air-tight, and we should provide the receiver with a mercurial valve.

Delicacy of test.

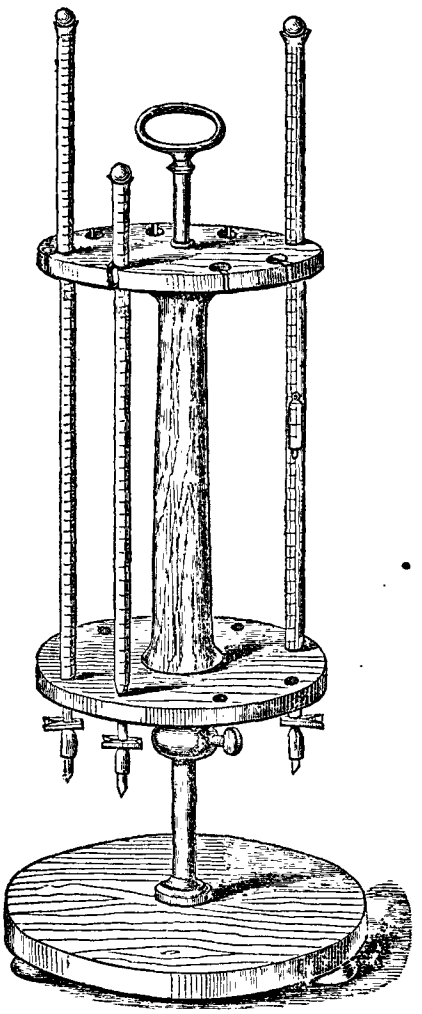
Normal urine when tested gives no reaction for alcohol under any circumstances unless alcohol has previously been taken. If we add one-tenth grain of absolute alcohol to two ounces of urine, and afterwards distil, we get a reaction very distinctly, which shows the great delicacy of the test. Only one source of fallacy exists with regard to it, and that is, that a small quantity of ether of some kind or other may be present, and that ether would, of course, in the process which we shall have to consider presently, be decomposed, and also be transformed into acetic acid and increase it. It is possible, for example, when we drink Greek wines, which contain a great quantity of aldehyde, that a quantity of that passes into our urine. There is not much physiological value in that fact, but nevertheless it is to be considered.

Dr. Dupré's new method of determining small quantities of alcohol.

Now, then, we have a quantity of alcohol so obtained from urine, and we want to determine how much it is. The tenth of a grain of alcohol in two ounces of water would not admit of any specific gravity determination. It would not be possible to immerse any instrument, or to put that small quantity on a balance sufficiently fine to determine that, and therefore it is necessary to take a somewhat circuitous but

still a quite certain route, and that is, we take the distillates and oxidise the alcohol therein contained to acetic acid, and determine it by quantitative analysis, or even make a salt of it. Alcohol does not combine with any other body; we cannot increase its weight; we cannot retain it in any way; whereas acetic acid combines with many, and owing to this property the quantity of the acid can be very easily determined, even in solutions. This is done in the following way: We enclose the distillate with a certain quantity of the dichromate and sulphuric acid mixture in a flask, and stop it air-tight with an india-rubber stopper, and tie it down well by means of wire. This bottle we now heat for two hours in a water-bath at a certain temperature, never amounting to boiling. During that time the whole of the alcohol is transformed into acetic acid. Then when we have oxydised the alcohol we have to distil that over, and for that purpose it is only necessary to distil the mixture down to one half in the same bath in which we have got the acetic acid. We now determine the acidity of our distillate by applying to it a caustic soda solution, a so-called standard solution, a solution of which we know the strength, and so ascertain the amount of acetic acid contained in the distillate. According to this plan the following experiments were made. The experiments on the large scale mentioned above were not so made, but resulted in the isolation of the pure absolute alcohol.

Transformation of alcohol into acetic acid.



Apparatus for applying Standard Solutions.

Experiment with Rhine Wine upon a Man.—The subject of the experiment voided all urine at 10.30 a.m., and took 10 oz. of Rhine wine containing ·1 oz. by measure of absolute alcohol. While the urine passed at 10.30 had yielded no tests indicating the presence of alcohol,

Experiment with Rhine wine upon a man.

at 11.30 a.m.	2 oz.	of urine passed	contained alcohol.
at 12.30 p.m.	$1\frac{3}{4}$ oz.	ditto	ditto
at 1.30 p.m.	$1\frac{1}{2}$ oz.	,,	contained no alcohol.
at 2.30 p.m.	1 oz.	,,	
at 3.30 p.m.	$1\frac{3}{4}$ oz.	,,	
at 4·30 p.m.	$1\frac{1}{2}$ oz.	,,	
at 5.30 p.m.	3 oz.	(2 oz. distilled)	

APTENDIX.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

The urine from 5.30 p.m. to 9.30 a.m. of the next day, 13 oz. in all, was distilled repeatedly until it amounted at last to $\frac{1}{4}$ oz.; it contained no alcohol.

When the reactions which were yielded by the urine which contained alcohol were compared to those of fluids containing a known amount of alcohol, it was estimated that less than $\frac{1}{10}$ (one-tenth) of a grain of alcohol was present in all. In this case, therefore, less than $\frac{1}{4000}$ of the alcohol taken appeared in the urine.

Experiment with Bordeaux wine upon a man.

Experiment with Red Bordeaux Wine upon a Man.—The subject emptied his bladder at 11 a.m., and the urine was found to be free from alcohol. He then drank 8 oz. of red Bordeaux wine, containing 1 oz. by measure of absolute alcohol. The urine passed at 12 o'clock (noon) measured $5\frac{1}{2}$ oz. and contained alcohol, but only the slightest trace, less than $\frac{1}{6000}$ of the whole taken. $2\frac{1}{2}$ oz. passed at 1 p.m.; 2 oz. passed at 2; 1 oz. passed at 3; 2 oz. passed at 4 o'clock p.m., were all quite free from alcohol.

Experiment with rum upon a man.

Experiment with Rum upon a healthy Man.—The subject emptied the bladder at 11 o'clock p.m., took 2 oz. of rum of almost proof strength, and went to bed half an hour afterwards. All urine passed during 12 hours succeeding was collected, and amounted to 13 oz. After the addition of a little sulphuric acid it was subjected to distillation and 5 oz. of distillate were obtained. This was made alkaline and again distilled until $1\frac{1}{4}$ oz. of distillate were obtained. This was again made alkaline and 1 oz. of fluid drawn off. Of this last fluid 1 cubic centimetre mixed with the chromic acid test gave only the slightest possible reduction, and that only after some time. In order to obtain an estimate of some kind of the quantity of alcohol contained in the 1 oz. last distillate, 1 cub. centimetre of absolute alcohol was mixed with 2,000 CC. of water. 1 cub. cent. of this mixture added to 1 cub. cent. of chromic acid test gave a strong reduction, and even $\frac{1}{2}$ cub. cent. gave a slight effect, which became more marked on standing. We may therefore estimate that the last distillate contained less than 1 alcohol in 2,000 water, or the 1 oz. less than $\frac{1}{5}$ of a grain. Consequently of the whole of the alcohol consumed less than $\frac{1}{2000}$th part reappeared in the excretion.

Analysis of urine in regard to alcohol of great importance in study of treatment of acute diseases.

The question of the analysis of urine in regard to alcohol is of the utmost practical importance in reference to the treatment of fever and acute diseases, in fact any diseases whatever. Of late years the practice has arisen of treating diseases, particularly fevers, with large quantities of alcohol. This practice was mainly introduced by the late Dr. Todd, of King's College Hospital. In some cases there 30 and 40 ounces of brandy were consumed by a single patient in 24 hours, and according to the records which were kept, those persons experienced no disadvantage whatever from taking those enormous quantities of alcohol. 20 ounces of absolute alcohol would kill any ordinary healthy person if he drank it in 24 hours, but with these fever patients the higher their fever the more alcohol could they consume, and apparently without any disadvantage to themselves, but rather the contrary. Now there came, of course, the question, What becomes of this alcohol? Is it excreted? Is it used merely as chloroform is, only to produce anæsthesia, and does it then go away again or not? and Dr. Dupré therefore made the experiment here related.

Experiments with wine and brandy upon a case of typhus fever.

Experiments with Wine and Brandy upon a case of Typhus Fever.—The patient took 6 oz of. brandy daily, and on some days additional quantities of wine.

First day of exp.—Total urine from 24 hours 20 oz.; distilled with acid; alkali and acid, as in the experiment with rum. 1 oz. of final distillate contained less than $\frac{1}{7}$ grain of alcohol.

Second day.—6 oz. of brandy and $18\frac{1}{2}$ oz. of wine. The last distillate of 1 oz. contained decidedly less than $\frac{1}{2}$, a little more than $\frac{1}{3}$ of a grain of alcohol.

Third day.—6 oz. of brandy and $15\frac{1}{2}$ oz. of wine. The last distillate of 1 oz. contained less than $\frac{1}{4}$ grain of alcohol.

Fourth day.—6 oz. of brandy only. The final distillate from 620 cub. cent. of urine, amounting to 1 oz., contained less than $\frac{1}{3}$, a little more than $\frac{1}{4}$ of a grain of alcohol.

Fifth day.—6 oz. of brandy only. The last distillate from 630 cub. cent. of urine contained less than $\frac{1}{5}$, a little more than $\frac{1}{10}$ of a grain of absolute alcohol.

Sixth day.—6 oz. of brandy only. The last distillate was oxydized by chromic acid, and the acetic acid produced was estimated; it indicated less than $\frac{1}{2}$ grain of alcohol.

Controlling experiment upon water.

Seventh day.—6 oz. of brandy. The fæces were examined exactly like the urine, and less than $\frac{1}{10}$ grain of alcohol found to be present. $\frac{1}{2}$ grain of alcohol was added to 18 oz. of water and distilled as the urine in the foregoing experiment. The last distillate of 1 oz. contained more than $\frac{1}{3}$, only a little less than $\frac{1}{2}$ grain of absolute alcohol.

Conclusion.

Now we see here the quantities of alcohol which proceed from the typhus body are not larger than those which would pass from an ordinary healthy person; consequently it was quite clear that these enormous quantities of alcohol taken are consumed in the economy, are oxidised. Whether they are beneficially consumed or otherwise must remain for future research to determine; but I have not the slightest doubt, from my own experience, that the giving to typhus patients considerable quantities of wines and alcoholic drinks, not concentrated, but refreshing, stimulating, good, well-tasting drinks, containing not much sugar, is one of the most beneficial things that can be done.

These researches might be multiplied. In fact they ought to be spread over a much larger number of cases.

Physiological effects of alcohol.

We will now consider, for a short time, the physiological effects of alcohol, in order to make our case complete. It is found that alcohol, when taken in large quantities, before it produces collapse and intoxication lowers the temperature of the body considerably. Experiments have been made upon drunkards, or at least people who are in the habit of drinking a great deal, and getting what is popularly known as "mellow." If we take such a man, and let him drink as much as he can and likes, we find that his temperature when he is in that state is considerably decreased, even by one or two degrees. In ordinary persons who take the quantity of alcohol which I propose to make the standard, namely, two ounces in a given time, no lowering of the temperature takes place, but rather a slight increase, a quarter of a degree or so, but not more.

Drunkenness diminishes temperature of body.

Moderate quantities of alcohol warm the body.

Preserving power of alcohol.

There are yet some reactions of alcohol which should be mentioned. A reaction of alcohol which we make use of is its property of attracting water, by means of which it precipitates albumen. When we mix the alcohol with white of egg albumen is precipitated. For a time this precipitate is soluble in water, but after a certain time it is no longer so. The anatomical specimens which we have in our museums are all preserved in that way. The water is withdrawn from them by the alcohol, they are repeatedly steeped, and ultimately they are kept in alcohol almost unchangeable. Alcohol is also made use of for the preservation of many kinds of fruit, such as cherries. It is a very curious fact that the pulp of fruit has a very great power of retaining alcohol, so much so that in the making of wines in France it is very well known that there is more alcohol contained in the mure,

Fruit preserved in alcohol. Cherry brandy.

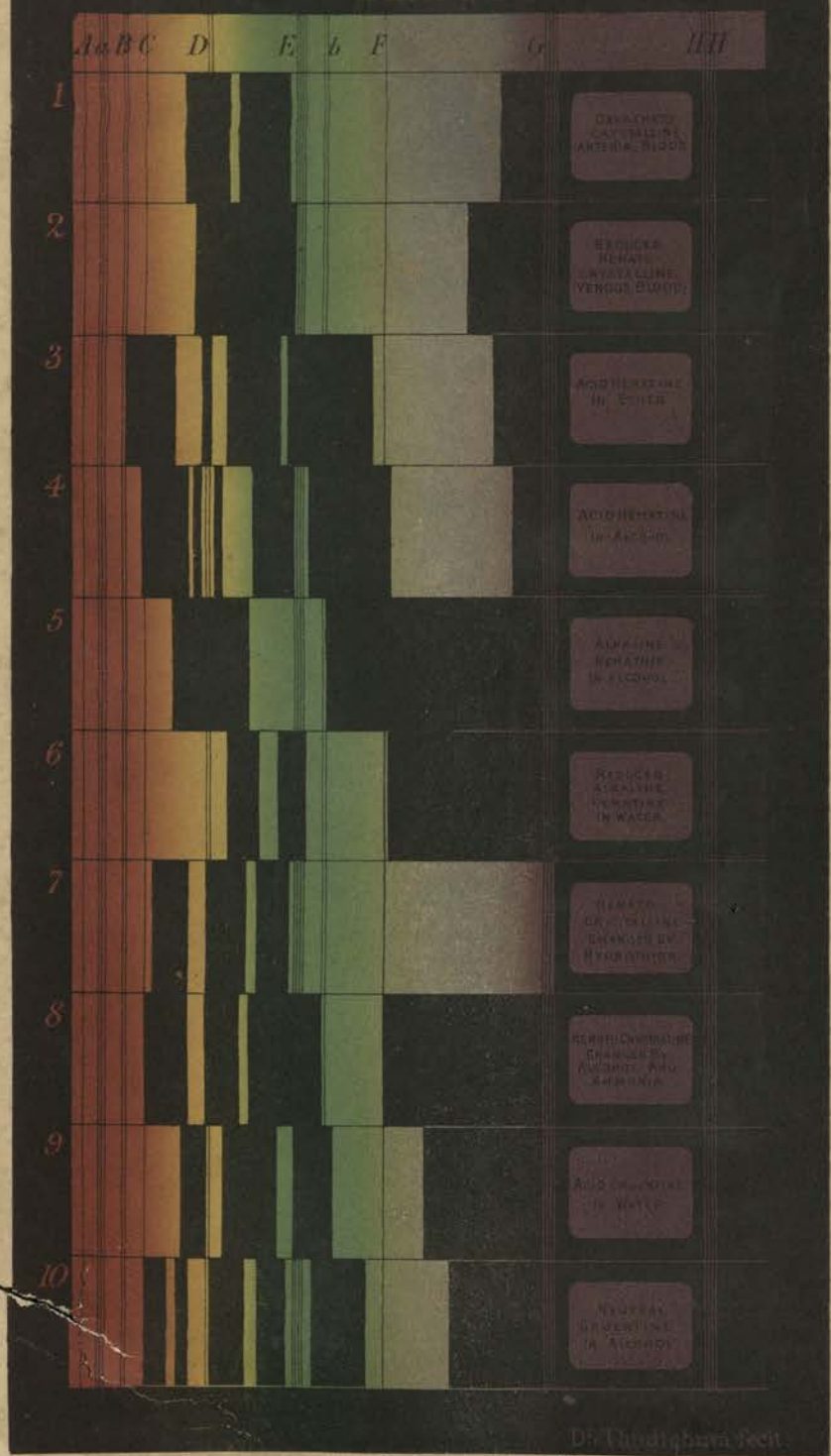
or the residue of the stalks, and the husks of the grapes, than there is in the wine which flows out, and that it is necessary to press the murc very strongly in order to obtain the alcohol which is in the mixture of murc and wine. And so when we steep pears, or apricots, or peaches, or any of those many fruits which are preserved in France, we always find that they attract a large quantity of spirit, and the liquid which we press out of the fruit itself is much stronger in respect to alcohol than the liquid in which it is suspended. Thus in eating brandy cherries we eat more concentrated brandy than we would drink if we were to drink the liquid in which they are kept.

Large amount of alcohol consumed in England.

I will for a moment consider the large quantities of alcohol which are consumed in this country. In England there are annually consumed many millions of barrels of beer. Wine is not comparatively much drunk in this country, but brandy is in enormous quantities. The tax upon alcohol as a whole realizes more than 10,000,000*l.* of revenue, and we can see, therefore, that alcohol is drunk by almost the whole of the population, with no very great exception. There is no doubt that by this practice of drinking alcohol in large quantities, particularly what are called "raw spirits," many diseases are engendered, and in London in particular a vast amount of the disease which shows itself in the hospitals is caused by the consumption of enormous quantities of porter on the part of the labouring classes, which may range up to 16 pints a day. If we observe labourers at work, in building houses, for example, we sometimes see them throughout the day drinking porter by the half pint or pint, and the potman comes round from the public-house every hour or half hour with fresh supplies; and this independently of what the labourer will drink at the public-house after his work is over. These cases furnish the staple of particular forms of kidney disease; and the habit of drinking large quantities of spirits and beer is to be deprecated as highly dangerous and objectionable. But when from this the conclusion is drawn that alcohol ought altogether to be abandoned, and that we all ought to do without any alcohol, I must say that that is one of the most overstrained propositions that could be made. Alcohol, when we have worked and are fatigued, is a great restorative and stimulant and food, and one of the greatest necessities of human life; and perhaps there has been no time and no nation in which some kind of alcohol has not been used, and mostly in the largest number of cases beneficially. If we do not exaggerate the quantity which we introduce into our stomach we will never have reason to fear that our kidneys will be damaged by that quantity of alcohol which will pass through them and be excreted.

Alcohol is a beneficial stimulant and restorative.

Plate 1.



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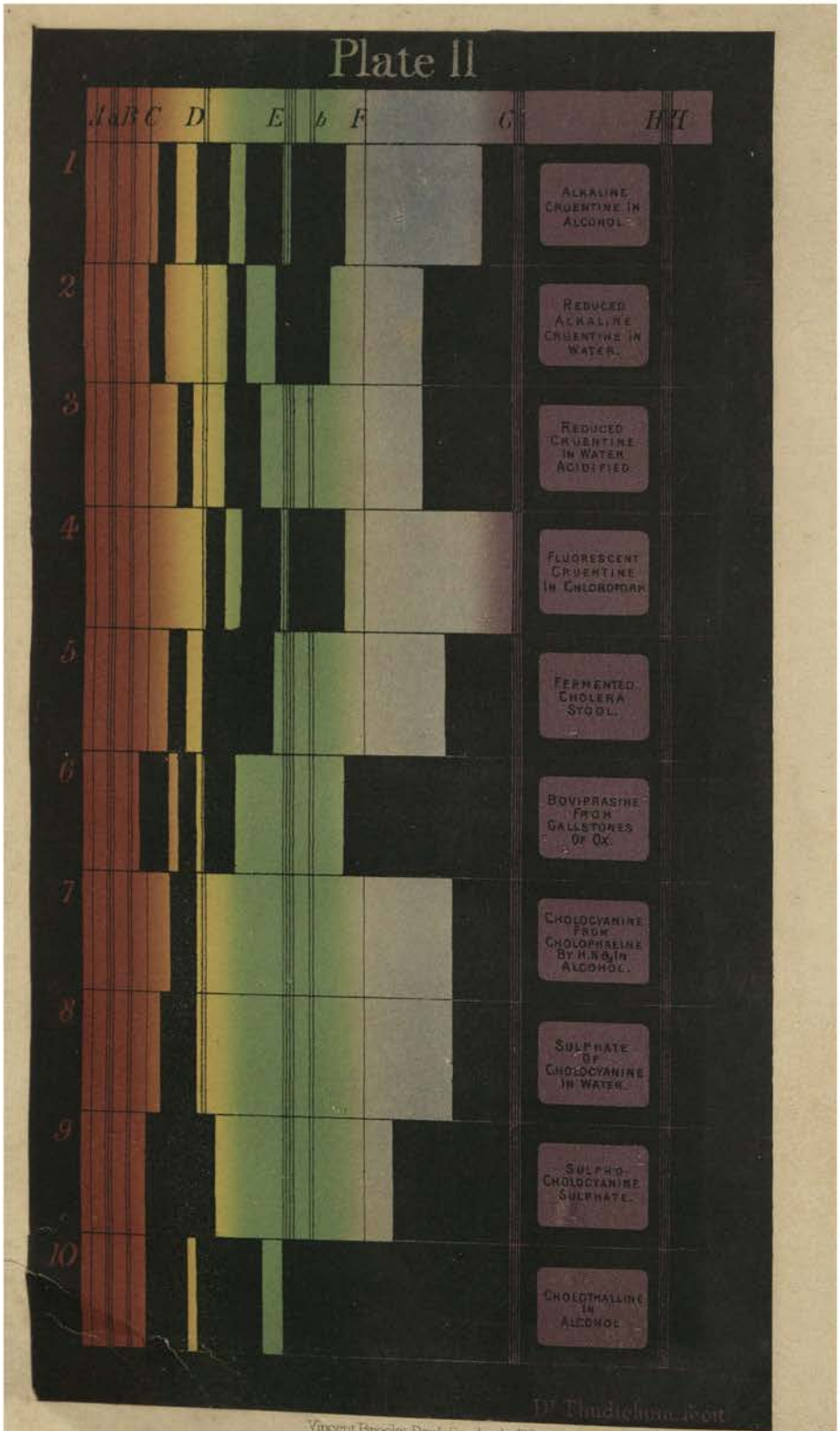
Explanation of Plate I.

The top spectrum represents the continuous spectrum of the sun, with the main sun-lines indicated by Fraunhofer's letters. The dispersion is about equal to that of a sulphide of carbon prism of a refracting angle of 60 degrees.

1. Hematocrystalline in the oxydised state, being the spectrum of arterial blood, plainly termed blood-spectrum.—(See p. 197.)
2. Hematocrystalline in the reduced or deoxydised state, being spectrum of venous blood.—(See p. 198.)
3. Acid hematine in ether or four-banded hematine spectrum.—(See p. 201.)
4. Acid hematine in alcohol, or five-banded hematine spectrum.—(See p. 200.)
5. Alkaline hematine in alcohol spectrum.—(See p. 202.)
6. Reduced alkaline hematine in water spectrum.—(See p. 203.)
7. Hematocrystalline changed by hydrothion.—(See p. 199.)
8. Solution of cruor treated with alcohol and caustic ammonia.—(See p. 200.)
9. Acid sulphate of cruentine in water. (See p. 204.)
10. Neutral cruentine sulphate in alcohol, or five-banded cruentine.—(See p. 205.)

Plate II



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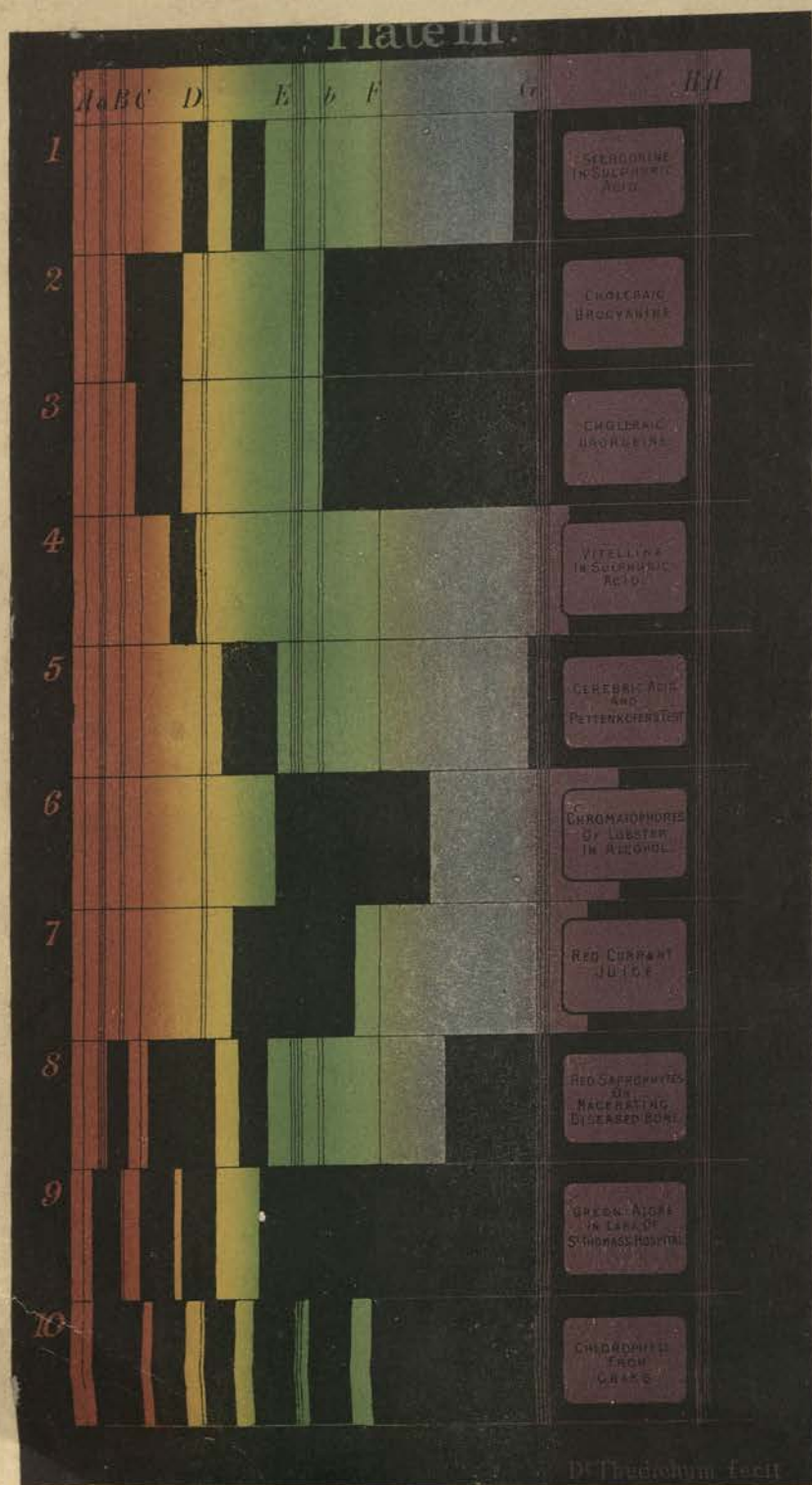
Explanation of Plate II.

Normal sun-spectrum with sun-lines indicated by letters.

1. Alkaline cruentine in alcohol, or four-banded cruentine.—(See p. 205.)
2. Reduced cruentine in watery solution.—(See p. 206.)
3. Reduced cruentine in water acidified, being spectrum of dilute solution of cruentine sulphate.—(See p. 207.)
4. Fluorescent cruentine in chloroform. Compare the neutral fluorescent cruentine in chloroform, diagram, and description on p. 204.
5. Fermented cholera stool.—(See p. 159.)
6. Bovifprasine from gallstones of ox.—(See p. 230.)
7. Cholocyanine from cholophaeine by nitric acid, dissolved in alcohol. —(See p. 228.)
8. Sulphate of cholocyanine dissolved in water.—(See p. 228.)
9. Sulphate of sulpho-cholocyanine. Concentrated solution.—See p. 228.)
10. Cholothalline in alcohol.—(See p. 229.)



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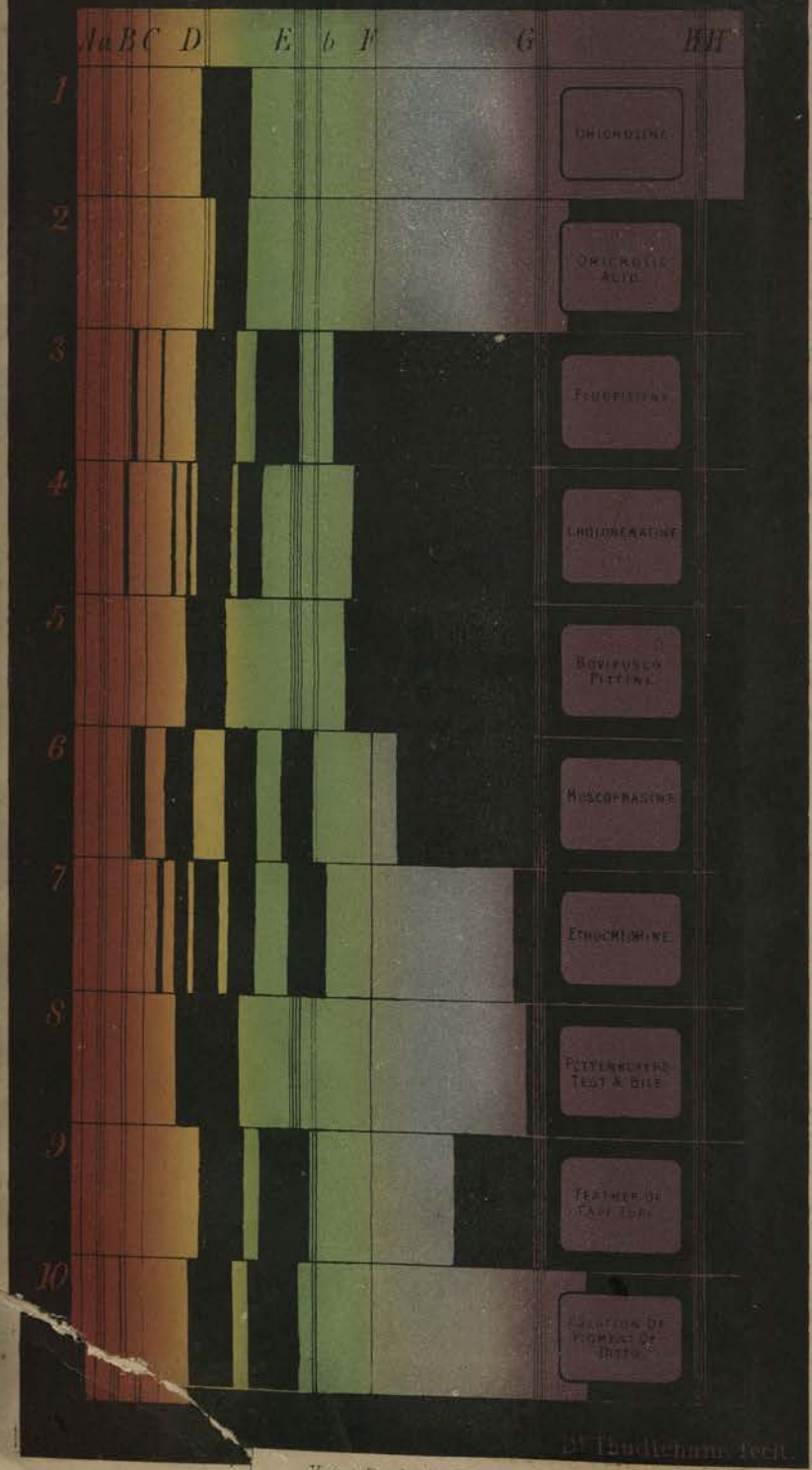
EXPLANATION OF PLATE III.

Solar spectrum with principal lines and letters.

1. Stercorine in sulphuric acid.—(See p. 158.)
2. Choleraic urocyanine in alcohol.—(See p. 248.)
3. Choleraic urorubine in alcohol.—(See p. 248.)
4. Vitelline or lecithine from yelks of eggs in sulphuric acid.—(See p. 161.)
5. Cerebric acid and Pettenkofer's test.—(See p. 161.)
6. Chromatophores of lobster; alcoholic extract.—(See p. 191.)
7. Red currant juice.—(See p. 191.)
8. Green alcohol extract of red algæ growing on macerating diseased bone.—(See p. 191, where there is also a diagram of the spectrum of the red algæ themselves.)
9. Alcohol extract of green cellular algæ in lake of St. Thomas's Hospital.—(See p. 193.)
10. Alcoholic solution of chlorophyll from grass.—(See p. 193.)

Plate IV



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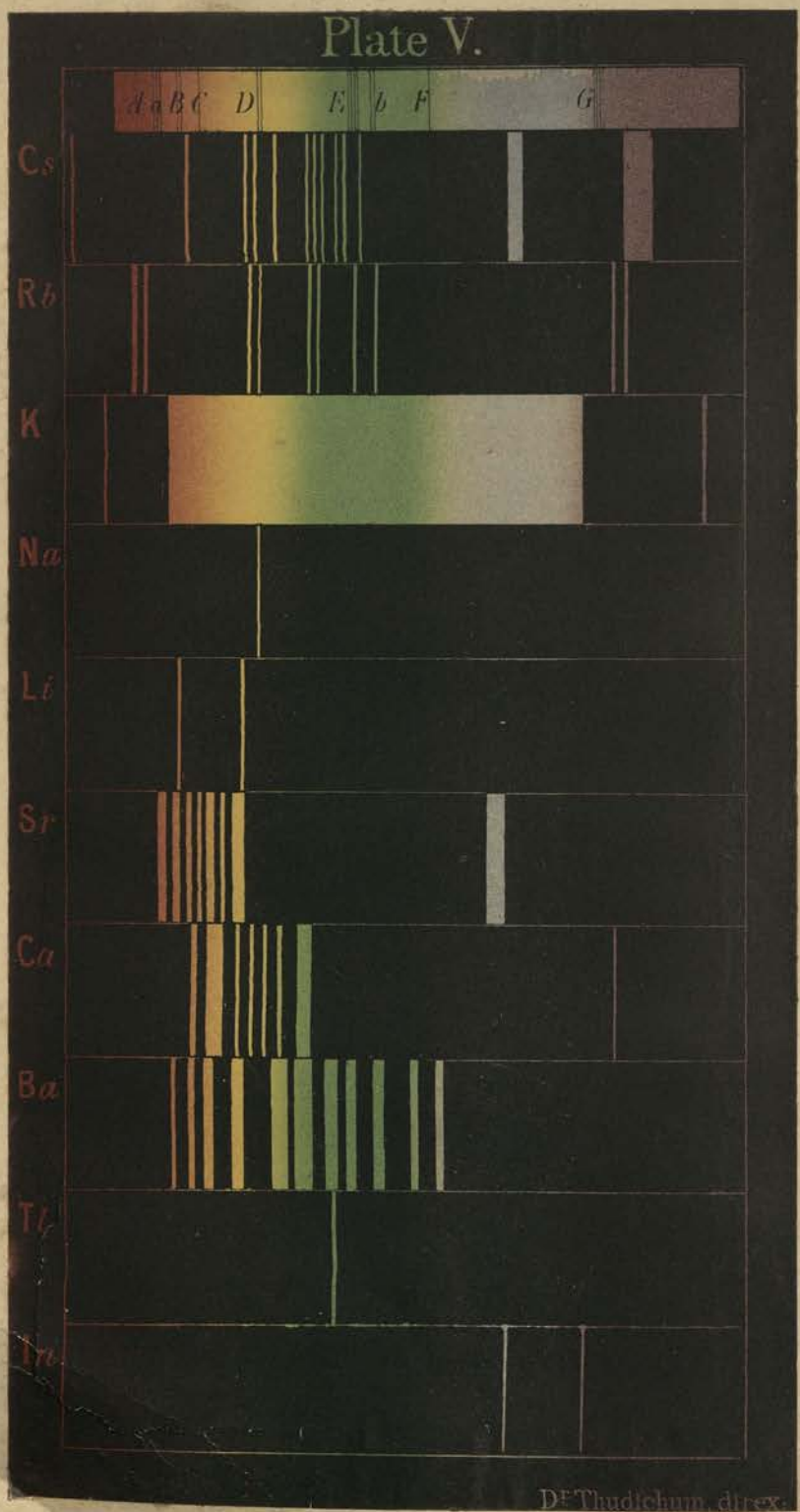
Explanation of Plate IV.

Solar spectrum with principal lines and letters.

1. Omicholine in ether.—(See p. 247.)
2. Omicholic acid in ether.—(See p. 247.)
3. Fluopittine in alcohol.—(See p. 214.)
4. Cholonematine in ether.—(See p. 229.)
5. Bovifuscopittine in alcohol.—(See p. 230.)
6. Muscoprasine in alcohol.—(See p. 331.)
7. Ethochlorine in ether.—(See p. 231.)
8. Bile and Pettenkofer's test.—(See p. 232.)
9. Red feather of Cape Lory (Turacus albo-crystatus.)—(See p. 197, footnote.)
10. Alkaline solution of the pigment of the red feather of this bird.—(See p. 197, footnote.)

Plate V.



Dr Thudichum, direx.

Vincent Brooks Day & Son, London WC.

Explanation of Plate V.

Section of solar spectrum with lines and letters.

Cs.—Spectrum of cæsium; 13 lines are represented, of which the red one, in the ultra-red heat region, is most remarkable and most difficult to observe.—(See p. 178.)

Rb.—Rubidium. (See p. 178.) All ten lines are represented. In this and the cæsium spectrum the continuous portion of light similar to that which appears in the potassium spectrum has not been represented, in order to fully define the lines in yellow and green.

K.—Potassium. Two bands, one red, one violet and portion of continuous spectrum. A feeble red luminosity at *a* has been omitted. —(See p. 178.)

Na.—Sodium. (See p. 177.)

Li.—Lithium. (See p. 178.)

Sr.—Strontium. (See p. 179.) Its eight bands are all represented.

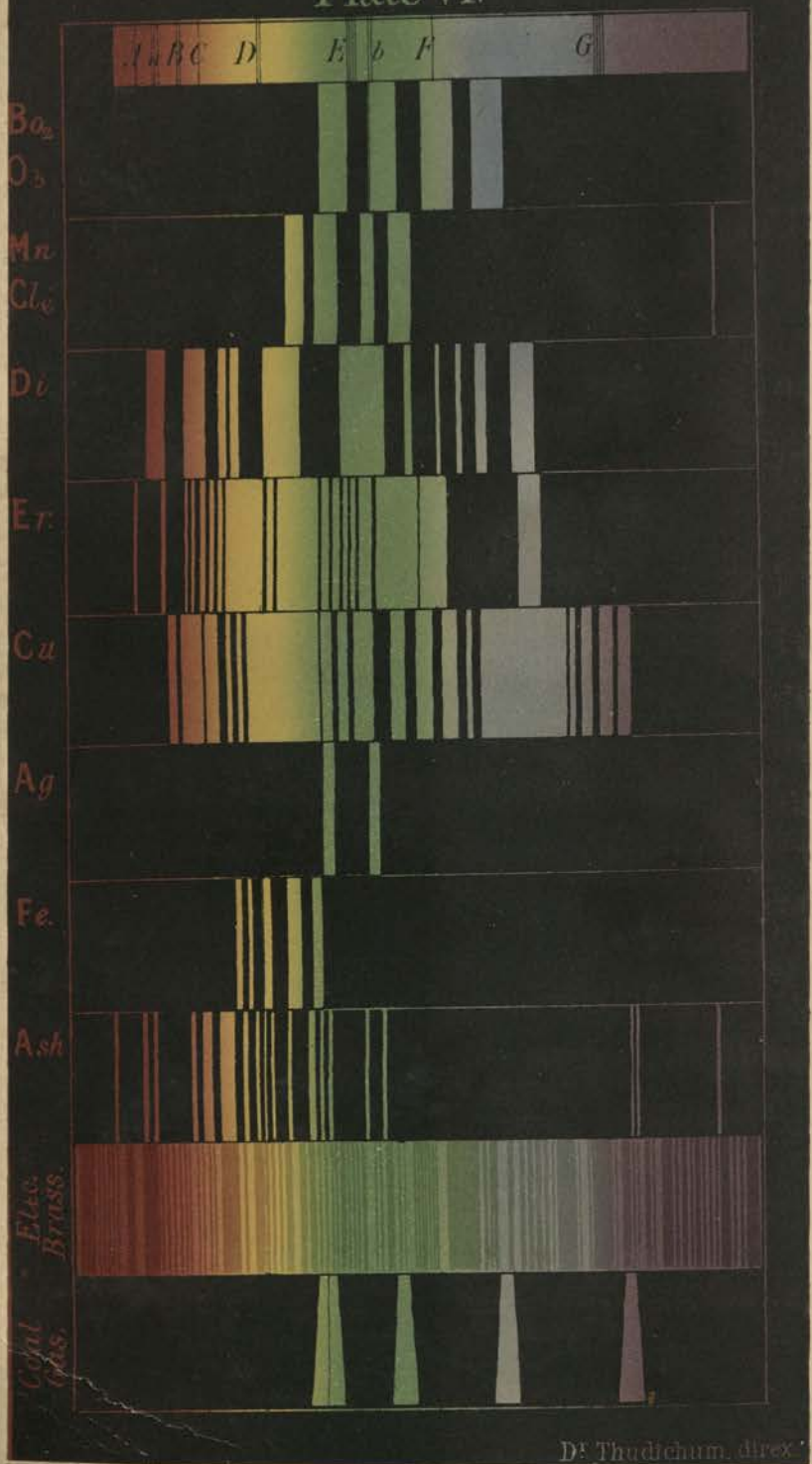
Ca.—Calcium. (See p. 179.) Of the nine calcium bands only eight are represented. A feeble line close to one of the four narrow lines in the middle has been omitted.

Ba.—Barium. (See p. 179.) Of the 15 barium lines only 11 have been represented, as being the best definable and easily seen with every good spectroscope.

Tl.—Thallium. (See p. 180.)

In.—Indium. (See p. 180.) Name derived from its blue coloured vapour and blue and violet band.

Plate VI.



Dr. Thudichum, direx.

Vincent Brooks, Day & Son, London W.C.

Note to the Maps which illustrate Dr. Buchanan's Report.

THE object of these maps is to convey to the eye a general notion of the position and boundaries of each district, and of its broad geological features. They have been printed from an electrotype plate of the Index Map of the Ordnance Survey, supplied by that Survey. The district boundaries on the one map, and the geological lines on the other, have been obtained by photographic reductions from larger maps, by Mr. J. B. Jordan, of the Mining Record Office. The geological lines, which have been engraved by Mr. J. W. Lowry, show with accuracy and considerable detail the distribution of the surface geology. The colouring has been done by Mr. W. Bone, the colourist of the Geological Survey. Mr. Whitaker has kindly superintended the preparation of this map, using unpublished as well as published sheets of the Geological Survey. He and Mr. Topley have added a very useful section, exhibiting the relation of the several formations to each other.

The map of the Geological Survey that was actually employed in the preparation of the report measures, for the area here represented, about 110 by 53 inches, or upwards of 40 square feet—a scale large enough to show particular houses. It is evident that the little geological map here given does not pretend to furnish any authority for the statements of the report; and that from its scale many points cannot be demonstrated upon it.

Thus (1) Narrow tracts of alluvium along streams are not shown. (2) Brickearth is not separated from gravel. (3) The divisions of the Bagshot Beds are not given—they are of small moment. (4) The divisions of the Lower Greensand are not shown, and what is more important, (5) The divisions of the Hastings Beds into sands and clays is not made—these divisions are made in nature by no long and well-defined boundaries, but by very irregular and multitudinous lines which could not be exhibited on this small map. (6) Faults are not marked, and (7) Of the formations that are shown, very small detached patches are, from the necessity of the case, omitted.

What the geological map does profess to exhibit, viz., the distribution of the main formations, of the broader tracts of alluvium, and of the more important surface coverings of gravel and the like, it exhibits in a very exact and reliable way. Its only known inaccuracy is that, in a small area of the northeast of Kent, and again over a large tract in the neighbourhood of Chichester, there are certain gravels which are not shown by stippling. These gravels are only mapped in certain unpublished documents of the Geological Survey, and time did not permit of their being copied, reduced, and engraved. But they have all been carefully considered in the statements of the report.—G. B.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

GEOLOGICAL MAP OF THE SOUTH-EAST OF ENGLAND (KENT, SURREY & SUSSEX) REDUCED FROM THE GEOLOGICAL SURVEY, 1868.

To illustrate Dr. Buckland's Report.

Scale 10 miles to 1 inch.

MAP SHEWING THE
REGISTRATION DISTRICTS
OF
KENT. SURREY AND SUSSEX.

The figures refer to the order of the districts in regard of their consumption mortality, in the first table of Dr Buchanan's report.

PUBLIC HEALTH.

ELEVENTH REPORT

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL.

WITH

APPENDIX.

1868.

Presented pursuant to Act of Parliament.

LONDON:
PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1869.

TO THE LORDS OF HER MAJESTY'S MOST HONORABLE PRIVY COUNCIL.

My Lords,

In obedience to the Public Health Act, 1858, I have the honour of herewith submitting to Your Lordships, for presentation to Parliament, my Report of the proceedings which Your Lordships under that Act directed to be taken during the year 1868. And for the present purpose I treat as part of that subject-matter the proceedings which Your Lordships directed to be taken under the Vaccination Act, 1867.

I am, my Lords,
Your Lordships' obedient servant,
JOHN SIMON.

Medical Department of the Council Office,
8, Richmond Terrace, S.W.,
March 31st, 1869.

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MEDICAL OFFICER'S REPORT.

I.—Vaccination.

The superintendence of Public Vaccination in England occupied during the whole of the year 1868 a more than ordinary share of the attention of the Lords of the Council. For on the first day of the year the new Vaccination Act, 30 & 31 Vict. c. 84, came into operation; and, from then onwards, my Lords were constantly engaged in proceedings, such as the Legislature intended to be taken, for the improvement of our public vaccination in respects where the system had hitherto been at fault. New Vaccination Law.

The nature of the defects which required correction had been very fully explained in successive annual reports of this department, particularly in those from the second to the sixth inclusive; and as far back as 1859 my Lords had communicated to the Poor Law Board, for the assistance of local authorities contracting for public vaccination, an exposition of the broad principles of arrangement on which contracts must in future be based if the defects in question were to be prevented. In 1868, with the new law, the time had come when this merely recommendatory mode of dealing with very serious evils could no longer be considered sufficient; and my Lords accordingly saw fit to issue express regulations for the purpose, by an Order of Council bearing date February 18th, 1868. Of the regulations thus issued, a copy is subjoined to this Report, as Appendix No. 2. The great object was that public vaccination should no longer be so excessively subdivided among times and places and persons as to have needless difficulties put in the way of its effective performance; and with this object the regulations provided, as their general effect, that the public vaccinator under ordinary circumstances should vaccinate only at public stations, and at no station oftener than once a week, and, if in a town district, only at one station therein; that no two public vaccinators should in any case act for one and the same district; and that the division of towns into vaccination districts should not go beyond certain limits of smallness. Also, with reference to section eight of the new Act, a special regulation was made, limiting the extent to which re-vaccination at the public expense might be given. New regulations affecting contracts.

The new law did not abrogate any of the existing contracts for public vaccination, but it tended to make new contracts in many cases desirable; and thus during the year new arrangements, which had to be conformed to the new law and to the regulations operating under it, and which my Lords had to consider in more or less detail, and for the most part very minutely, with the respective local authorities or with the Poor Law Board, were proposed by more than a seventh part of the entire number of New contracts.

vaccination authorities of the country. The year has in this way been one of very great improvement in our system of public vaccination. Also in other and ordinary ways influences for improvement have been at work.

Ordinary inspections, and awards to vaccinators.

The systematic inspection which goes on under their Lordships' orders extended during the year to nearly half the public vaccination of England, namely, to 1,749 vaccination districts, comprised in 312 different unions or parishes: each inspection involving, first, an inquiry into the state of vaccination in the district; secondly, where requisite, a notification to the authority of defects found in the local arrangements for carrying the law into effect, and advice as to the changes required; and thirdly, in suitable cases, a recommendation of the vaccinator for reward under section five of the Vaccination Act, and in accordance with the system described in my ninth report. Of the money which Parliament had placed at their Lordships' disposal for this purpose my Lords distributed 2,753*l.* 2*s.* The number of vaccinators to whom gratuities were given was 345; namely, 129 who received first-class, and 216 who received second-class, gratuities. The gratuities of each class differed of course very considerably in money value in different vaccination-districts, just as the several contract-earnings differed. Where a public vaccinator was having so few vaccinations as to be only earning from his board of guardians some 20*s.* or 30*s.* a year, the supplementary payment by the Privy Council was necessarily quite insignificant as money, and, except that it implied an honorable recognition of service, might scarcely have seemed worth the trouble of formal transmission and acknowledgment; but, on the other hand, in many cases the payments were such as probably to be in themselves welcome additions to the often scanty stipends of the recipients. The largest aggregate payment of the year (a first-class gratuity on 2,738 vaccinations) was 136*l.* 18*s.*; the smallest (a first-class gratuity on 19 vaccinations) was only 19*s.*

Outbreaks of small-pox.

My Lords during the year had occasion to correspond specially with the guardians of the unions of Congleton, Enfield, Epping, Sheffield, Tendring, Tiverton, and Totnes, with regard to outbreaks of small-pox reported in those jurisdictions respectively.

Supply of vaccine lymph.

The applications made to this department during the year for vaccine lymph were 14,099; in answer to which were supplied as follows:—131,390 charged ivory points, 1,059 charged squares of glass, and 9,792 charged capillary tubes. Particulars as to the sources whence this lymph was derived are given in Appendix No. 1. Of the 14,099 applications, in answer to which lymph was given, 11,085 came from medical practitioners (including 1,462 poor-law medical officers) in England and Wales; 1,721 from Ireland, and 511 from Scotland; 566 from the army; 73 from the navy and emigration department; 101 from colonies, and 42 from diplomatic and other foreign services. My Lords, as usual, took means during the year to satisfy themselves as to the undiminished efficiency of the lymph which is supplied under their directions.

With reference to this branch of the service, my Lords had their attention drawn to a system which is in vogue in some parts of the continent, for maintaining continuous sources of lymph-supply for the human subject by keeping a succession of calves inoculated with the specific contagium; and their Lordships had a report prepared for them by Dr. Ballard on the arrangements which are in use abroad for this so-called "animal vaccination." Further information, however, is requisite before any final opinion can be formed on the question of making more or less use of the system for purposes of our National Vaccine Establishment; and therefore on the present occasion the subject cannot be written of in detail.

Animal vaccination.

Fourteen of the twenty-two stations which are sources of lymph-supply for the National Vaccine Establishment, and also two stations which do not supply lymph for the public service, are used as educational stations under their Lordships' Order of December 1st, 1859. My Lords during the year inquired as usual into the conduct of the educational business of these stations, and received on this subject, as on the subject of the lymph-supply, a report which was entirely satisfactory.

Educational status.

II.—GENERAL SANITARY ADMINISTRATION.

During 1868, as usual, in various cases within purview of the general sanitary laws of the country, my Lords had to communicate with the respective local authorities concerning action to be taken under those laws. The authorities thus communicated with were 50; including 14 of the special boards of the metropolis, 5 extra-metropolitan vestries, 15 boards under the Public Health and Local Government Acts, and 16 boards of guardians. In seven of the cases, local inquiry by an inspector under their Lordships' direction was deemed necessary, viz., at Walton-le-Dale in Lancashire, at Bootle in the same county, at Thetford in Norfolk, at Clifton-Hampden in Berkshire, at Barnet in Middlesex, at Luton in Bedfordshire, and at Dunstable in the same county.

Occasional sanitary inquiries.

In the systematic sanitary inquiries which my Lords have for ten past years been carrying on, as to the distribution of disease in England and the circumstances by which it is regulated, there was in 1868 an almost complete pause; owing in some measure to the fact that the working power of the department was accidentally for the while much reduced; and in other part, because with the present commencing second decennium of sanitary responsibility, a new cycle of work had to be begun, and a great deal of consideration had to be given to questions of improvement of system.

Systematic sanitary inquiries.

The department has, however, been indebted to Dr. Ballard, medical officer of health of the parish of Islington, for a very interesting voluntary contribution to knowledge, in the form of a report on the statistics of sickness treated at the public expense in Islington during the last 12 years; and this report by Dr. Ballard is subjoined. See App. No. 3.

Sickness treated at public expense.

The only respect in which my Lords in 1868 extended their previous series of systematic inquiries as to the distribution and circumstances of disease, was an inquiry concerning the prevalence

Venereal diseases in London.

of venereal maladies among the poorer parts of the civil population in London; and for this inquiry Mr. Wagstaffe, one of their Lordships' inspectors, collected some detailed information which is given in his subjoined report. See App. No. 4.

III.—AUXILIARY SCIENTIFIC INVESTIGATIONS.

Pathological investigations.

The pathological work of the department was continued during 1868 in both of the directions to which I referred in my last yearly volume; and details of this work are given by Dr. Sanderson and Dr. Thudichum in their respective subjoined reports. See App. Nos. 5 and 6. Dr. Sanderson, continuing from the previous year the very important investigation of tubercular disease, has now succeeded in throwing new light upon a large part of that subject-matter; and Dr. Thudichum, in the chemical field of research, has made considerable further progress in continuation of the line of 1867.

IV.—ADDITIONS TO SANITARY LAW.

Pharmacy Act, 1868.

An important addition to the sanitary law of the country was made last year by the passing of the Pharmacy Act, 1868. This statute is chiefly directed against evils to which I particularly drew attention in my sixth report, as attaching to the practice of pharmacy by unqualified persons, and to the too unrestricted procurability of poison for criminal purposes. The new law is to be worked by the Pharmaceutical Society, under the general sanction and supervision of my Lords of the Privy Council. It provides that in future no one shall begin any such pharmaceutical practice as involves a sale of poisons, unless he have first passed a sufficient examination in pharmaceutical knowledge; and that poisons shall not be purchaseable except with such personal identification as would probably hamper anyone who intended to make criminal use of them; and that the keeping and sale of poisons generally shall be subject to regulation under the Act. It also affirms an important principle in regard of the adulteration of drugs, by enacting that the provisions of the Adulteration of Food Act of 1860 shall be extended, mutatis mutandis, to the sale of drugs.

V.—QUESTION OF STATE INTERFERENCE TO PROVIDE FOR THE DISINFECTION OF PROSTITUTES.

Proposals to extend the operation of the Contagious Diseases Act, 1866.

The inquiry of the department into the prevalence of venereal diseases among the civil population was intended to contribute some of the elements necessary for judging a question which of late has been much agitated before the public: the question, *whether it is expedient to have in this country a systematic sanitary superintendence of prostitutes.* During the last few years, under the provisions of special Acts of Parliament—the so-called "Contagious Diseases Acts" of 1864 and 1866, a system of this sort has been administered on a small scale, by the War Office and Admiralty, at certain military and naval stations; and recently,

while these departments have been proposing to extend their own operations with respect to the two public services which they direct, the more general question has been raised by the advocacy of a voluntary association formed for the purpose of promoting the extension of the Contagious Diseases Act, 1866, to the civil population of the United Kingdom.

Special case of Army and Navy, as distinguished from that of Civil Population.

There are here two questions which I think cannot be too strictly distinguished: the question concerning the army and navy, and the question concerning the civil population. It has not been any part of my duty to advise on the former of these questions; and I now only advert to it for the sake of greater clearness in proceeding to discuss the other. It seems to me that prostitution and its attendant diseases, in their relation to the army and navy, are, in two different points of view, matter of public concern and responsibility; first, because the military and naval services at their respective stations are essential determining causes of prostitution, and the State, which for its own purposes keeps those masses of male population unmarried, cannot claim to be indifferent to the result; and, secondly, because the specific diseases which arise in that mode of life occasion so enormous a quantity of temporary disablement in the two services as to be of pecuniary importance to the entire tax-paying community. These I apprehend are the grounds on which rests all that has yet been done by the Legislature with reference to venereal diseases: grounds which are in the utmost degree exceptional as regards the nature of the case: and to argue from such a case to the case of the civil population would manifestly be a confusion of judgment. Of the venereal diseases of the civil population, English sanitary law has not hitherto taken any special cognizance; and whether this neutral state of the law ought or ought not to be abandoned is a separate question, of far more intricacy than seems to be generally imagined, and which on all accounts certainly deserves most careful consideration.

Requirements involved in proposal concerning civil population.

In proceeding to discuss this question, I may conveniently first refer to the programme of the association which I have mentioned—the "Association for promoting the Extension of the Contagious Diseases Act, 1866, to the Civil Population of the United Kingdom." The Association contends "that sufferers under any kind of [venereal] contagious disease are dangerous members of society, and should, so long as they are in this state, be prevented from communicating it to others; . . that common prostitutes should be subject to a compulsory medical examination, and to compulsory detention in hospital as often as they are found diseased, and as long as they continue so; . . that, for the reception of prostitutes suffering from venereal disease, hospital accommodation should be provided in all towns where such persons congregate."* To give a notion of the quantity of hospital accommodation which would be requisite to satisfy this programme, I may observe, for instance, that London is conjectured

* Report of Association, sections 2, 33, 32.

MEDICAL OFFICER'S REPORT.

to have some 18,000 women whose living is gained by prostitution;* and that, according to one of the secretaries of the society, on any given number of prostitutes, always about one-third may be assumed to be diseased.† If, instead of insisting on these colossal estimates, we take only half their total result, the plan would require for London alone the creation and maintenance of new hospital accommodation nearly equal to that which is now given by the twelve general hospitals of London for all bodily diseases put together: accommodation, namely, for 3,000 patients. The charge of maintaining (independently of the cost of constructing) such lazarets as the above would probably be at least 100,000*l.* per annum: and their construction would probably represent a first cost little short of half a million of money; besides all which there would be the considerable annual charges for police arrangements and medical inspections. This for London alone! And the requirements of other large towns would probably be of like proportions.

And how, and by whom, to be met? and on what grounds?

Demands like the above are evidently not likely to be met by voluntary contributions. The result, if to be got at all, can only be got under action of law; and any such law, whether empowering the central government to defray expenses out of proceeds of general taxation, or empowering municipalities to assign local funds for the purpose, is, of course, in relation to minorities, compulsory. Now, it is quite certain that, rightly or wrongly, the proposed appropriation of money would, in the eyes of very large numbers of persons, be to the last degree odious and immoral. In most municipal constituencies there are swarms of persons who already find it no easy matter to satisfy the collectors of rates and taxes; they would see the prostitute kept in hospital at their expense for weeks or months, not necessarily from the exigencies of severe illness of her own, but essentially that she might be made clean for hire, lest any of her users should catch disease from her; they would remember in contrast, that for themselves wonderfully little is done by authority to protect them against adulterations of food, or against false weights or measures; and they might regard it as a strange caprice of law which should oblige them to contribute to the cost of giving an artificial security to their neighbour's looseness of life. It seems to me very important to measure beforehand the degree in which such arguments would be valid, or rather to consider on what principles (if any) the proposed intervention of law is to be justified.

Primâ facie, venereal diseases are not any concern of Government;

I suppose it may be assumed that public policy is very decidedly in favour of marriage as against promiscuous fornication; that the latter, however powerless may be laws to prevent it, is, at least, an order of things which no State would willingly foster; that, whereas it has some inherent inconveniences, among which is the liability to specific contagious maladies, such drawbacks from its attractions are not in their kind a matter for general social regret;

* Appendix of Assoc. Report, p. 22.
† Mr. Curgenven, on the Contagious Diseases Act of 1866, p. 7.

that venereal diseases are, in principle, infections which a man contracts at his own option, and against which he cannot in any degree claim to be protected by action of others—the less so, of course, as his option is exercised in modes of life contrary to the common good; that thus, primâ facie, the true policy of Government is to regard the prevention of venereal diseases as matter of exclusively private concern. *Caveat emptor!* And though it must be admitted that to some extent the consequences of promiscuous fornication spread beyond the persons of the original performers; the infections of the brothel being oftentimes carried into simultaneous or subsequent wedlock, and in some cases fixing their obscene brand even on the offspring of such marriages; this horrid fact is only one of many which might be cited, where innocent wives and children participate more or less severely in consequences which husbands and fathers have earned. To be wife or child of a drunkard or a gambler involves evils against which the State does not affect to give security; and, primâ facie, the dependent interest must be equally unprotected by the State against harms which that other sort of looseness may bring on it.

but this with qualification.

I am very far from thinking that the above are the sole considerations to which regard must be had in deciding such questions as the present. But they seem to me to define a position which ought not to be abandoned, except under strong compulsion of circumstances, and with reasonable prospects of success. Evidently, if venereal diseases were now the same gigantic scourge and terror which they were some 350 years ago, when they inspired Fracastoro's poem, and if curative medicine had continued as powerless against them as then: if we saw them still raging as great intractable epidemics, impeding national movements, and forcibly occupying the mind of society with all sorts of lazarous presentations: the reasons for legislative action, *provided such action could be effectual*, might be stronger than the reasons for neutrality, and considerations as to the personal ætiology of the disease might perforce have to be subordinated to the urgency of a public danger.

Medical grounds on which the proposal has to be judged:

The cardinal questions, then, are two:—First, does the detriment which venereal infections cause to the public health reach those limits at which principles generally preferable ought to be exceptionally abandoned by the State? Secondly, would the good which can be got through State interference in this matter be enough to reasonably compensate for the cost at which it would have to be attained? I must confess that I cannot with any approach to confidence answer either of these questions affirmatively. As regards the first of them, I have not the least disposition to deny that venereal affections constitute a real and great evil for the community; though I suspect that very exaggerated opinions are current as to their diffusion and malignity; but since the resources of curative medicine against them are constantly becoming stronger and stronger, it seems probable that the worst of them will year by year become less and less important (as endangering life or limb) in cases where infection may obtain. It may also be anticipated

that the greatly improved knowledge which late years have given to the medical profession with regard to the venereal contagia will spread, and not very slowly spread, through the minds of the general public, and will soon very much reduce the number of those sad cases where infected men give syphilis to their wives and offspring. On the other hand, as regards our power of preventing venereal diseases by such a superintendence of prostitution as is proposed, it is certain that no appreciable good would be got except with much organization, and at very large cost of money; and there are strong reasons for believing that the gain so purchased would, on analysis, be found to belong very predominantly to those kinds of venereal disease in which the community has little or no permanent interest.

what is the magnitude of the mischief?

First, as regards the actual quantity of venereal disease current in this country, and the importance of such disease to the public health, it is to be remembered that under the head of "venereal diseases" are included three chief sorts of disease, and of course in each sort many different degrees of severity. The three sorts to which I refer, and which in any given person are not incompatible with one another, are gonorrhœa, pseudo-syphilis, and true syphilis. *Gonorrhœa* is never even temporarily of much importance to women, nor ever, unless very exceptionally, of much permanent importance even to men; but yet thus far it is not a quite unimportant infection, that in men it is often extremely inconvenient, indeed sometimes involves for a time painful and even disabling complications, and cannot absolutely be said never to leave permanent local damage behind it. *Pseudo-Syphilis*, or so called "simple chancre," is a form of ulcer which may be of considerable local destructiveness, and is often attended by inguinal buboes, but leads to no specific ulterior consequences. *True Syphilis*, arising as "hard chancre," or in other less characteristic primary affections, involves an outbreak or successive outbreaks of so-called "secondary symptoms;" which, though almost invariably amenable to medical treatment as they arise, and probably in an immense majority of cases not of more than transient importance to the person attacked, are yet not infrequently a more or less troublesome relapsing illness, and sometimes, even in spite of treatment, a long subsequent danger to life; and this true syphilis is of permanent interest to society, partly because of the cases (though comparatively very few) in which it is intractable in the person of the original sufferer, but still more because of the indefinite duration of time for which he or she may at intervals be capable of infecting others, and because the issue of syphilitic parents is apt to perish during utero-gestation, or to be born more or less syphilitic. In seeking to estimate, without exaggeration, the harm which society suffers from venereal diseases, and the good which preventive measures may possibly effect, it is, of course, essential to observe the distinctions between the above-described three sorts of disease: above all not to use the word "venereal" as if it were synonymous with "syphilitic;" and it is also essential that whatever purports to be statistical evidence on the subject

should be evidence on a sufficiently large and impartial scale. The report of the "Association for Promoting the Extension of the Contagious Diseases Act to the Civil Population" gives some statistics which might lead to an impression that in London from one-fifth to one-third of the sick poor are suffering from "a contagious disease of the gravest character, which is constantly transmitted from parent to offspring;" but the contents of Mr. Wagstaffe's subjoined report (App. No. 4.) satisfy me that no sufficient grounds for any such impression exist: rendering it, I think, highly probable that, of the sick poor who at any given moment are receiving medical relief under the poor law and at dispensaries and general hospitals in London, only about 7 per cent. have venereal disease of one kind or another, and that only in about half this proportion the form of disease is true syphilis. Again, a piece of the experience of the Children's Hospital in Great Ormond Street, as quoted in the report of the Association, may seem to suggest that "about one-fifth" of the sick children of the poor are sick with immediate consequences of inherited syphilis; but on inquiry I find that, of 118,590 children of the poor treated during the last ten years for all sorts of diseases at the Ormond Street Hospital, the proportion recorded to have been syphilitic has been only 1½ per 100. Thus, in both cases the quantity of evil appears to be many times less than advocates of legislative interference may imagine; and it must be remembered that London probably illustrates the utmost dimensions which the evil can attain in this country.

MEDICAL OFFICER'S REPORT.

how far is the mischief preventable?

Then, as regards the preventability of venereal diseases, even the abstract question (abstract I mean from considerations of cost) is by no means an easy one. Especially we are in want of exact discriminative information as to the good which other countries have got from their sanitary superintendence of prostitution. I believe it to be the fact that, even under strict systems of police, prostitutes in very large proportions escape the intended supervision; and that in their evasive traffic so large a dissemination of venereal diseases may be kept up as to leave in net result very little apparent success to be boasted of. Let it be assumed, however, that, in any place where circumstances are favourable, "venereal diseases" in mass may be greatly reduced under such a system: but there remains as an unfortunate accident of the case, that this reduction might least of all affect those sorts of disease in which society is incomparably most interested; and in the absence of exact records on this point, expectations ought, I think, to be very moderate. For the various local states which most habitually spread the infection of true syphilis are apt to be in themselves such slight and painless affections as almost or entirely to escape the patient's notice; and indeed in women primary syphilitic ulcers, and other local states capable of infecting with syphilis, not only very often pass unnoticed by the patient herself, but have often been overlooked in examinations made expressly for their discovery. And with reference to proposals that particular inspections of women should take place on the information of men whom they have infected, insuperable difficulties are created in the case

of true syphilis by the very long incubation-time of the primary infection: an interval generally of at least three weeks, and capable apparently of extending to six weeks or more: during which time the inoculated part presents absolutely no sign of infection; and at the end of which time the infected man may (for obvious reasons) be in utter ambiguity as to his infectress.

and with what difficulties? and at what proportionate cost?

When the question of preventing venereal diseases is considered as one of administration and finance, some of the above facts become important difficulties. It is proposed that the organization should take equal cognizance of all sorts of venereal disease: indeed this, if the organization were in existence, would seem practically inevitable; partly because of uncertainties and precariousness of diagnosis; partly because cases, taken in the order of their permanent interest to society, would very often be in inverse order to that which the relative urgency of personal sufferings would dictate. And thus, so far as the extinction of true syphilis is to be deemed the essential object of the system, the organization would in two ways tend to be disproportionately expensive: on the one hand, because expending a very large share of its strength on diseases of no permanent importance to society, and, on the other hand, in such measure as cases of true syphilis would escape the intentions of the system.—Further, when the administrative question is considered, not as national and one, but as distributed among many local authorities, a new sort of difficulty presents itself. Whatever good can be got from a sanitary superintendence of prostitution, if worked with uniform strictness through the entire country, the good will not only of course diminish, but will diminish at an immensely increasing rate of diminution, in proportion as the system is not universal and uniformly strict; so that a local expenditure which would give remunerative results, if other places were acting on the same system, might easily, in the contrary case, appear comparatively unproductive. This has been a chief point in the case of those who have pressed for an extension of the present venereal diseases law; and the Association's report has for one of its chief texts, "Free communication between localities, fatal to success of Act in limited districts."

Practical conclusions:

The broad result in my mind from the various above-stated considerations is that at present I very decidedly refrain from recommending any change in that neutral position which English law has hitherto held in regard of the venereal diseases of the civil population. So far as my present knowledge enables me to judge, I believe that any departure from that position could do little but embarrass and disappoint.

as to compulsory legislation;

That under a well-planned national system, obligatory in its local operation, and stringently directed from the centre, with an enormous establishment of lock hospitals, with prostitution universally submitted to strict methodical supervision by police, and with very frequently recurring minute surgical examination of the persons of prostitutes, a great reduction might be made in the present prevalence of venereal diseases among the civil population; and that as part of such reduction (though probably in comparison

but a small part) there would be a diminution in the prevalence of true syphilis; these are propositions which I do not dispute; but their very important converse has to be remembered, that, in proportion as the above conditions cannot be attained, the hope of results becomes chimerical. The conditions, I need hardly observe, are such as there can be no reasonable present expectation of seeing realized in this country; and I must add that, in the present state of my knowledge, I could not advocate any such legislation as would even approximately fulfil them. Not only do I doubt whether the evil can in any reasonable sense be said to call for the repugnant and very costly measures of prevention which alone could pretend to be of effect against it, but also I feel bound to press for something like proportion in the treatment of such matters. And recognizing how incomplete is hitherto our sanitary system, and particularly how little pressure is yet put on local authorities in matters of far more general importance to life: recognizing, for instance, that it is almost entirely a question of private charity whether fever hospitals exist in a town, and that such hospitals are most insufficiently provided: I cannot but think that during this state of things compulsory legislation in the present matter would be a disproportion not to be justified.

as to giving option to local authorities;

On the other hand I have to observe that the somewhat uncertain amount of good which very strict compulsory legislation might produce would less and less admit of being realized, in proportion as the provisions of law were non-compulsory; and a law, giving to local authorities or populations any considerable scope for option in the present matter would quite unquestionably be futile. Everyone knows how valueless such legislation has been in the greater part of the hitherto province of sanitary law, even as regards objects of foremost necessity to the public health; so valueless, that in all chief respects compulsory legislation has already had to be substituted for it; and the light of those experiences may be applied, mutatis mutandis, to the present extremely difficult and delicate subject matter. There probably would be detailed discussions, often indefinitely prolonged, and resulting in inharmonious conclusions, in innumerable vestries and town-councils and wardmotes; discussions which, if not to bear fruit, ought in the interests of decency to be deprecated; but of action, capable of giving success, there certainly would be little or nothing. It is true that under permissive law there have been exceptional instances of local exertion for other sanitary purposes; but even solitary instances of such exertion could not in the present matter be anticipated; for here the peculiar discouragement would exist, that no town could be sure of satisfactory results from its own superintendence of prostitution unless other towns, in communication with it, were acting upon the same system.

as to legislating for a voluntary system;

In a particular proposal, which I think it my duty to mention, permissive legislation, of a sort which would almost entirely rest on a system of voluntary contributions, has been contemplated;

and this proposal was received last year with some favour by the Committee of the House of Lords which had the Contagious Diseases Act under consideration.* The proposal, viewed in relation to its professed aim, is of course open in the very utmost degree to the objections which I have just stated generally against permissive legislation; indeed, I can scarcely conceive that, if enacted, it would in any single case be of good effect; and there is a different point of view in which I would venture to submit that its admissibility (as well as that of any permissive legislation) requires to be most cautiously considered. For it seems to me that the proposed legislation, powerless though it would be for any sanitary result, would in principle be the thin end of a wedge; that the question of its acceptance or rejection is, as precedent, of fundamental importance; that, between permissive general legislation to-day and compulsory general legislation to-morrow, there would stand but the question of expense. In courses called tentative it is so easy to drift into positions which become pledges, that I venture to press this consideration. Whether the venereal diseases of the civil population are henceforth to be deemed matter of public concern, whether the civil fornicant may reasonably look to constituted authorities to protect him in his commerce with prostitutes, is the principle which I conceive to be at stake. And I would repeat my opinion that, if that principle is affirmed, the responsibilities implied in it cannot be adequately met without stringent compulsory general legislation.

as to local Acts.

Whether particular municipalities wishing to exercise within their respective jurisdictions special powers in relation to venereal diseases might properly be let acquire such powers by purely local Acts of Parliament, is, I think, a somewhat different question; and possibly such special Acts (provided they contained proper obligatory provisions) might, in certain cases, be conceded without any sacrifice of the real principles which are at stake. Every such case would then have to be judged on its own merits. But as regards any general legislation, whether compulsory or permissive, in regard to the venereal diseases of the civil community, my conclusion is very decided that at present I cannot recommend any such legislation.

Supplementary remarks:

Finally, there are some incidental considerations to which I beg leave briefly to advert.

Prostitution, and the ways of reducing it:

Among arguments put forward to recommend a general superintendence of prostitution, there is one which seems to have gained for the proposal a considerable quantity of non-medical, particularly clerical, support. The report of the Association, namely, alleges "that a collateral but not unimportant result

* I describe the financial basis of this proposal as "almost entirely" voluntary contribution. The proposal, as I understand it, is that Government should be authorized to confer the requisite police powers for sanitary superintendence of prostitution on any local authority shown to have at command (as by voluntary contribution) the proper hospital accommodation for such purposes. And the proposal seems to assume that, if lock hospitals were established by voluntary contribution, the local authority could provide (presumably from proceeds of rates) for the cost of the medical inspections and police arrangements.

which inevitably follows the establishment of preventive measures is the improvement in the moral and social condition of the women;" and a memorial which was last year addressed to the then Lord President of the Council, by the President of the Royal College of Physicians and others, supported the view "that, of the unfortunate women who are subjected to these restrictive and sanitary measures, a comparatively large proportion have been reclaimed." I believe it to be unquestionable that such women as have hitherto come under medical inspection have generally been influenced by it to become cleanlier in their persons, and that the brothels inspected by police are less apt than they were to be scenes of riotous disorder; changes, on which no doubt the users of those persons and places may congratulate themselves; but which cannot without extreme abuse of terms be described as of any moral significance. On the other hand, the last clause of the statement cannot fail to seem morally important to anyone who accepts it without reserve. I fear, however, that such hopes as it at first sight would seem to justify, as to possible moral results of a government superintendence of prostitution, would on any large scale show themselves essentially delusive; not, perhaps, as regards individual reclamations to be effected, even from brothels, by pure and kindly human contact, but as regards the statistics of prostitution, broadly and practically considered. For I apprehend that the concubinage-market, like other markets, tends to be fed according to demand; and that, if prostitution is really to be diminished, the principles of those who would diminish it must be preventive. Of the many roots of the evil some are practically immutable, but others will undoubtedly vary with the general moral sentitiments of the time. Always, of course, there are certain large quantities of mere brute passion, forcing at any price to have their way; and always, in our present social state, there are large unintelligent masses of human life with little sense of right and wrong, and much of abject poverty ready to sell itself for food, and even more of uneducated frivolous temperament. But if these be regarded as in my present sense "fixed" elements (though indeed all of them are happily susceptible of reduction) a comparatively very variable force is represented in the influence of public opinion. That parents of the educated classes regard with immeasurably different degrees of interest the chastity of their daughters, on the one hand, and the continence of their sons, or future sons-in-laws, on the other, is a fact which probably has its basis in a doctrine of supposed general consequences; but knowledge which is supplied in studying the venereal diseases of the civil population—a knowledge of the mischief and misery which a young man's transient incontinence may be preparing for his whole future domestic life, certainly gives room for consideration whether these ingredients of the one case ought not to be more popularly understood. The only state of things which can be regarded as essentially antagonistic to prostitution is the system of early marriages: which, in this respect, commends itself equally on moral and physical grounds; for, in proportion as it is accepted, the promiscuous intercourse of

the sexes ceases to excuse itself by circumstances, and the chances of venereal infection fall to the lowest level they can attain.

Hospitals for diseased prostitutes.

Also in conclusion I would beg leave (though perhaps superfluously) to protect parts of my above argument from misapprehension. In the proposals which I have had to criticise, hospitals for diseased prostitutes have not come under discussion as charitable institutions, but solely as elements in a machinery proposed to be constituted by law for giving an artificial security to promiscuous fornication. In the latter sense I may have seemed indifferent to their existence; but in the other sense, if this occasion permitted, I would willingly plead in their favour. For some thirty-five years of hospital-surgery in London have given me the amplest opportunities of knowing what physical miseries (as well as what worse mental states) attach to the career of prostitutes; and in this point of view I cordially agree with those persons who deplore the extreme insufficiency of hospital accommodation provided among us for prostitutes venereally diseased. The defect may not be for legal remedy, but not the less it is real, and I sincerely hope it may be dealt with by agencies appropriate to its nature. Such are not for me here to discuss. But considering how large a proportion of society has responsibilities of causation or connivance in that sphere of suffering and shame, and considering again what case for compassion even those who are purest from such responsibilities may recognize in states of human life so estranged and so bitterly punished, I should suppose that dictates of justice on the one side, and impulses of charity on the other, would respond, and not parsimoniously, to any well-considered appeal in the matter.

VI.—QUESTION OF CONSOLIDATING AND BRINGING INTO SYSTEM THE LAWS AND ADMINISTRATIVE AGENCIES WHICH CONCERN THE PUBLIC HEALTH.

I HAVE stated that during the past year much consideration has had to be given in this department to *questions of improvement of system* in the laws and legally constituted machinery which purport to provide for the public health of the country; and it may be convenient that in this place I briefly state my experience of the present system, and my opinion of the reforms which are wanted in it.

Spirit of the present sanitary laws.

It would, I think, be difficult to over-estimate, in one most important point of view, the progress which during the last few years has been made in sanitary legislation. The principles now affirmed in our statute-book are such as, if carried into full effect, would soon reduce to quite insignificant amount our present very large proportions of preventable disease. It is the almost completely expressed intention of our law that all such states of property and all such modes of personal action or inaction as may be of danger to the public health should be brought within scope of summary procedure and prevention. Large powers have been given to local authorities, and obligation expressly imposed on

them, as regards their respective districts, to suppress all kinds of nuisance, and to provide all such works and establishments as the public health primarily requires; while auxiliary powers have been given, for more or less optional exercise, in matters deemed of less than primary importance to health; as for baths and wash-houses, common lodging-houses, labourers' lodging-houses, recreation grounds, disinfection-places, hospitals, dead-houses, burial-grounds, &c. And in the interests of health the State has not only, as above, limited the freedom of persons and property in certain common respects: it has also intervened in many special relations. It has interfered between parent and child, not only in imposing limitation on industrial uses of children, but also to the extent of requiring that children shall not be left unvaccinated. It has interfered between employer and employed, to the extent of insisting, in the interests of the latter, that certain sanitary claims shall be fulfilled in all places of industrial occupation. It has interfered between vendor and purchaser; has put restrictions on the sale and purchase of poisons, has prohibited in certain cases certain commercial supplies of water, and has made it a public offence to sell adulterated food or drink or medicine, or to offer for sale any meat unfit for human food. Its care for the treatment of disease has not been unconditionally limited to treating at the public expense such sickness as may accompany destitution: it has provided that in any sort of epidemic emergency organized medical assistance, not peculiarly for paupers, may be required of local authorities; and in the same spirit it requires that vaccination at the public cost shall be given gratuitously to every claimant. The above survey might easily be extended by referring to statutes which are only of partial or indirect or subordinate interest to human health; but, such as it is, it shows beyond question that the Legislature regards the health of the people as an interest not less national than personal, and has intended to guard it with all practicable securities against trespasses, casualties, neglects and frauds.

The intentions frustrated in detail:

If, however, we turn from contemplating the intentions of the Legislature to consider the degree in which they are realized, the contrast is curiously great. Not only have permissive enactments remained for the most part unapplied in places where their application has been desirable: not only have various optional constructions and organizations which would have conduced to physical well-being, and which such enactments were designed to facilitate, remained in an immense majority of cases unbegun; but even nuisances which the law imperatively declares intolerable have, on an enormous scale, been suffered to continue; while diseases which mainly represent the inoperativeness of nuisance-law have still been occasioning, I believe, fully a fourth part of the entire mortality of the country. And when inquiry is made into the meaning of this strange unprogressiveness in reforms intended and in great part commanded by the Legislature, the explanation is not far to seek. Its essence is in the form, or perhaps I may rather say the formlessness, of the law. No doubt there are here and there other faults. But the essential fault is that laws which

ought to be in the utmost possible degree simple, coherent and intelligible, are often, in nearly the utmost possible degree, complex, disjointed and obscure. Authorities and persons wishing to give them effect may often find almost insuperable difficulties in their way; and authorities and persons with contrary disposition can scarcely fail to find excuse or impunity for any amount of malfeasance or evasion.

and how?

The many mere ambiguities and minor oversights of the law need not here be insisted on; for the broad jurisdictional state of the case is in itself enough to account for miscarriage.

Local authorities: in common health-areas:

Except where special health-areas have been constituted under local Acts of Parliament, or under the Public Health and Local Government Acts, the local administration of the nuisance-law in regard of its most rudimentary objects is not vested in one single authority for each place, but is distributed, with very disputable demarcation-line, between two. And as regards the distribution of voluntary improvement-powers in such places, there may be one authority for common lodging-houses, another for labouring classes lodging-houses, another for baths and wash-houses, another for burials; and all these authorities separate from the two authorities which have to do with nuisances and drainage and water supply, and from the authority which has to do with highways.

in special health-areas.

It is true that, where special health-areas exist, matters are on a better footing as regards the consolidation of nuisance-powers and improvement-powers in the hands of the town-council, improvement commission or local board; but just in these cases a new kind of evil crops up: for, except by accidental coincidence, these special health-areas do not form units of area in the population-statistics of the country; and it consequently very often occurs that these districts (which peculiarly might be expected to be able to show an intelligible balance-sheet in regard of their expenditure of life) have really no separate statistics even of their births and deaths. Also these special health-areas have not, except sometimes accidentally, any relation whatever to the areas of poor-law relief; and a medical officer of health acting for the health-authority of the town has no official relations with the medical attendants of the sick poor.

Central authorities.

Then (secondly) as regards central jurisdiction in nuisance-law and kindred matters, the conditions are equally unmethodical. Proceedings which stand to one another in the relation of first and second stages of legal intention are the responsibilities of two different chief ministries: on the one hand, inspectional and admonitory proceedings, such as my Lords of the Council direct through this department, in relation to local excesses of disease, and their causes; and, on the other hand, coercive proceedings, which the Secretary of State is empowered to take, in regard of defaulting nuisance-authorities: proceedings of the latter sort being hardly conceivable except on foundation of proceedings of the former sort. This of course is no insuperable difficulty; for the departments concerned can easily adjust their boundary line; but unfortunately in our sanitary code there are other and less superable wants of method. The essential responsibility

for superintending the state of the public health is integrally vested in the Lords of the Council; but fragments of co-ordinate responsibility in the same subject-matter are also vested (for purposes more or less special) in the Home Secretary and in the Board of Trade; and thus one given subject-matter may be under consideration in two or even three Government offices, and each of these offices be required to communicate with the public concerning it.

Relations of Government to localities.

Thirdly, as regards the relations between central and local authorities, a very unfortunate state of things is represented in the absence of certain lines of communication. Government is supposed to supervise the state of the public health: but Government may remain for long periods of time uninformed even of extremely important local outbreaks of disease. This is constantly happening with regard to typhoid fever and other nuisance-diseases of the country; and a very suggestive illustration of the fact is, that, when diphtheria was first beginning to re-appear on a large scale in this country after an interval during which the medical profession had lost all memory of it, very fatal local epidemics of what seemed a new disease were going on for two years (1855–7) in various parts of England, with the central authority of the country absolutely unapprised of the fact. In this connexion too it deserves notice, both as a matter affecting the relations of central to local jurisdictions, and indeed also as affecting the efficiency of the local authorities themselves, that, with regard to some essential elements for proper judgment as to the health of districts, the law does not even provide for the knowledge being systematically in existence. It provides, no doubt, that causes of death shall be registered; but no provision is made that the causes shall have been medically certified; and to my knowledge it has happened in regard of whole counties that, through the general absence of proper medical certificates, with the accompanying misuse of medical language by lay certifiers of death, very deceptive impressions have been given as to the local prevalence of particular diseases. A similar fault of system is shewn in the fact that no available medical returns are made of sickness locally treated at the public expense. Nor, I need hardly add, are any such returns made as to the sickness treated by our innumerable quasi-public medical charities.

Causes of the chaotic state of law.

It would be useless, though not difficult, to explain in detail how the above-described unsatisfactory state of law has come to exist. Broadly it represents two sets of causes. On the one hand, the legislature in all these matters has evidently meant to proceed very cautiously and tentatively; and the many successive stages of attempt, while co-apparent in the statute-book, show of course a good deal of awkward piecing and overlapping, and probably more or less of accidental inconsistency, as well as a certain quantity of ground not yet covered by legislation. On the other hand, the impulses to legislation have come from many different quarters, including two or three departments of Government; and simplifications and coherency of result, such as might have been attained if all had originated from or converged to a single chief ministry for

the subject-matter, are merits which, from the nature of the case, could not be expected.

Remedial legislation.

I venture to submit for consideration whether now the time has not come when a better state of things than I have described can be, and ought to be, constructed. For in regard of some very considerable parts of sanitary legislation, including the machinery by which effect is to be given to the law, the purposes of tentative proceeding have now, I apprehend, been amply fulfilled; and there exists undoubtedly a very urgent public need, that the intentions of the legislature in the present most important subject-matter should as soon as possible, and as completely as possible, be embodied, intelligibly and harmoniously, in clear consolidating law. In contribution to this result I avail myself here of the opportunity to submit some suggestions as to what, in my opinion, are the chief objects for endeavour, and what the broad outlines of such system as might easily be attained, for sanitary government in England.

Nuisance law:

A. That the nuisance-law of England (using the word *nuisance* in its largest sanitary sense) should be put on a satisfactory footing, as regards authorities and areas of jurisdiction, seems to me the first object to be aimed at; and the opportunity would probably be found convenient for making also some extensions which are wanted as regards the scope or object-matter of the present law. Of the chief objects which I think desirable under these heads, the following is a more particular statement:—

to be consolidated with local improvement law:

a. I think it essential that the separation which recent Sewage Utilization Acts have established between nuisance-authorities and sewer-authorities should cease; that every nuisance-authority should also be sewer-authority in the fullest sense of the word; that in the hands of this consolidated health-authority should also be vested all such powers as now attach to several different authorities and corporations for purposes of local improvements and inspections in the physical interests of the people, in regard of burial grounds, baths and wash-houses, labourers' dwellings, common lodging-houses, recreation-grounds, paving, lighting, &c.

jurisdiction in special health-areas:

b. That cities and towns with developed municipal government should constitute special health-areas, having as health-authorities their respective town-councils, improvement commissioners, or other local boards, is a present state of law which of course would be continued; and the utmost facilities ought also, in my opinion, to be given (akin to those which the Local Government Act now gives) for the creation of new special health-areas, and for the variation of existing special boundaries, where required by local conditions. It seems probable that ports and harbours, with all shipping contained in them, must at least to some extent be regarded as special health-areas, having the harbour-authority for health-authority; and, if so, that, for cases where it would be convenient, the harbour-authority might be empowered to appoint some permanent officer to act as health-authority in its stead.

in ports:

in common health-areas.

c. As regards places not constituted special health-areas, choice has to be made between several courses; and the one which on the whole

I think has great balance of advantages in its favour is that of consistently adhering to the intentions of Mr. Lowe's Nuisance Act of 1860, by letting the common health-areas be the union-areas of poor-law jurisdiction, and identifying the common health-authorities with the common destitution-authorities of the country. The poor-law division of the country is a long-accomplished and locally well-known division, which furnishes limits to many local relations, and, not least, fixes the Registrar-General's "districts" for statistics of population and births and deaths: every union has its administrative board, presumably of the best sort which the area can be expected to give for any purpose of local government, and carefully constituted on the double basis of rate-paying suffrage and ex-officio qualification, and moreover so constituted that each parish of the union is represented in it: and this authority has its fixed meeting-place and meeting-times: it has its permanent clerk, qualified in law: and it has, always acting in detail over the whole union-area, as visitors of the poor and their dwellings, a staff of other permanent officers, medical and non-medical. No approach to such organization as this exists for any other purpose in the rural districts of the country; and it would seem to me a simpler and safer course to bring the common health-service of the country within scope of that existing organization than to attempt a differently planned organization for objects exclusively of health. Among plans which may be conceived as alternatives to the above, it might be proposed to revert to some such parochial system as that of Sir Benjamin Hall's Nuisance Act of 1855, or to develop the parochial system of Sir George Grey's Sewage Utilization Act of 1865; but any parochial system, if not to be utterly abortive, would have to provide for the constitution of boards and offices for each parish with an elaborateness which would often seem most disproportionate; and the result when obtained would be a jurisdictional system conterminous with little except the system of church-rates. Other sorts of plan might aim at establishing a system of county-boards, with some sub-scheme, perhaps of descending scale, for smaller (say, at last parochial) sub-jurisdictions; but here again the law would fail, unless it provided for the boards and officers of the sub-jurisdictions; and all this apparatus, because of its novelty, would have to be planned so minutely, as compared with the actual work to be done in each rural sub-jurisdiction, that it could scarcely not seem excessive and pedantic. And in any of these alternative plans there would be difficulty in avoiding what, if it occurred, would be matter for extreme regret, an entire dissociation of the local health-machinery from that universal system of medical attendance which exists for purposes of the poor-law.

d. If, however, the common health-areas of the country are to be the areas of poor-law unions, and the local authorities acting for destitution are to be the local authorities acting for health, there are three conditions which I think ought to be observed. First, regard being had to the great extent of most rural unions, and to various other considerations, it is peculiarly necessary that

Relation of health-authority to authority for destitution: in common health-areas:

the authority should be well empowered to act through committees, both for divisions of district and for divisions of subject-matter; and probably it would be convenient that such committees should be able to include persons not members of the original board. Secondly, regard being had to the frequency with which neighbouring districts have joint interest in questions, as particularly of drainage and the like, each authority ought to have facilities, and in certain cases obligation, to combine for particular purposes, by committee or in entirety, with other neighbouring authorities. Thirdly, I think it scarcely less than essential that any law which connects for local administration the two services of health and poor-law relief should do so in a different form to that of the law now in force. At present in all common health-areas of the country the board of guardians of the poor is the nuisance-authority; but it is so *ex officio;* and this peculiar form of law not only gives to the health-interests of the place an undue appearance of being of secondary importance, but also sometimes leads the guardians to think themselves surcharged with duties foreign to their real business. It seems to me highly desirable that, if the two administrations are to be associated, the board should be appointed, *ab initio,* expressly for the compound purpose, and should be invested by law with a new title denoting its double functions as authority for health and destitution.

in special health-areas.

e. Within almost all special health-areas of the country the health-authority is, and I must assume will for the present continue to be, distinct from the destitution-authority of the place. I accept this as fact, but I doubt if it is to be deemed an advantage. I suspect it would generally be of benefit to municipal administration if one single board, with sufficient power of acting by committee, were elected for all purposes of local government, including the relief of destitution.

Local medical services under health-law.

f. As regards certain medical services to be locally rendered in aid of health-authorities as such, I think, first, that every health-authority should be empowered to appoint a special health-officer; secondly, that wherever there is a special health-area the appointment of a special health-officer should be imperative; thirdly, that for areas where the destitution-authority is also the health-authority, the rule ought to be that, if no special health-officer is appointed, each medical officer acting under the destitution-authority should be deemed health-officer within the limits of his own medical relief district.* I think it indispensable that everywhere throughout the country there should be an officer to whom the local authorities and the public may look for those definite occasional acts of inspection and certification which an amended health-law would certainly require from time to time to be executed, and to some of which I shall hereafter refer; but it is obvious that

* For brevity, I use the word "health-officer" without qualification: but I may observe that the functions for which I am here proposing to provide universally are only such few rudimentary functions as attach to a minor health-officer, and that the question of superintendent health-officers, acting for counties or other large areas, is one on which I do not at present enter.

in many of the common health-areas of the country occasions for this sort of action would be so few that probably the services might best be paid by fees. In all important special health-areas, on the other hand, the services would be more or less continuous; but it could only be in some very few cases that the duties of the health-officer in a single health-area would represent entire occupation of his time; and therefore, for other cases, it seems to me greatly to be desired, with a view to procuring proper cultivation of the required medical accomplishments, that the special health-officer of one town should be free to be special health-officer to another; and that the two parties concerned should so avail themselves of this freedom that the special health-officer might be able to dispense with ordinary professional practice, and that the towns employing him might be able to secure a very high quality of special service.

Extension of legal definition of "nuisance."

g. The system of summary procedure which is the essence of our modern nuisance-law (subject, of course, in certain cases to appeal to a superior court) ought in my opinion to be extended as far as practicable to all influences by which the public health is endangered, and the word "nuisance" for the purposes of the law to be applied to every such influence. Especially, it seems to me, that all such pollutions and obstructions of streams as may be of ill consequence to the public health ought to fall within the law of nuisance.

Regulation against recurrent nuisances.

h. With regard to all such sorts of nuisance as are likely to be recurrent or habitual, the central authority, and with its consent local authorities, ought, I think, to be able to make regulations and to affix penalty to breaches of them.

Proceedings.

i. All proceedings under the nuisance-law might, I believe, with advantage be open indifferently to any person aggrieved, and to the local authority, and to the central authority.

Other conterminous medical responsibilities:

B. Two very important medical responsibilities, not arising under the nuisance-law, nor under the poor-law, but created by special Acts of Parliament, have at present to be discharged, the one entirely, and the other almost entirely, by the respective destitution-authorities of unions and parishes, viz., first, public vaccination, and, secondly, medical relief in epidemic emergencies.

public vaccination:

a. The authority for public vaccination is now universally the destitution-authority, which in all common health-areas is identical with the nuisance-authority, but in all special health-areas is separate from it. Under the system I am suggesting, public vaccination in the common health-areas would remain substantially unchanged; it would be one of the health-functions of the double-functioned local authority; but as regards special health-areas, it would certainly admit of question whether public vaccination ought not rather to be a function of the consolidated health-authority than a function of the authority for destitution; and I am myself disposed to think that in those areas the transfer would generally be desirable.

action under Diseases Prevention Act.

b. Exceptional medical relief in epidemic emergencies (as requirable under the Diseases Prevention Act) is so essentially a

mere temporary increase of the ordinary medical relief of the poor, that I think it ought always to be a function of the authority which administers the ordinary relief. Thus, under present poor-law, the function would everywhere attach to the destitution-authority of the place. With regard to special health-areas, where almost universally the destitution-authority and health-authority are mutually independent bodies, the law ought to take security for all necessary co-operation of the two sets of officers; and this not only when the Diseases Prevention Act is in operation, but equally as to all ordinary relations between the preventive and curative jurisdictions.

Local medical functions attributable over larger areas.

C. Beyond the purview of such laws as I have yet spoken of, very important sanitary objects yet remain to be provided for by some sort of local administration. Such are the protection of the public against sale of adulterated and damaged food, and against malpractices of water-companies, and against offences under the Pharmacy Act; proceedings as to the diseases, especially the contagious diseases, of domestic animals; provision of skilled assistance to local magistrates when crimes against life are imputed, &c. As regards all these matters, some distinctive principles are involved, making it in my opinion for various reasons inexpedient that here the local authorities should be such as have hitherto been under consideration. One immensely important group of functions under the present head is to protect the public health against various kinds of commercial wrong; and if powers for this purpose are to be strongly and impartially exercised, it would seem desirable, first, that the areas of jurisdiction should be as large as conveniently may be, and then that the empowered authorities should rather be of magisterial type than consist of boards constituted by annual popular election. Probably the magistracy of boroughs and counties, as represented in courts of quarter-session, would be the best local authority in the matter; and it might, I submit, be required of each of these courts to appoint a public analyst, with definite duties under the adulteration laws, and with reference to public supplies of water, and various like matters. It seems to me that, for all health-matters not in the hands of nuisance-authorities or destitution-authorities, an uniform constitution of authority on this magisterial basis might very conveniently be provided; bringing more or less completely into one system the local supervision of branches of trade which concern life, and the local supervision of cattle diseases, and the local supervision of lunatic asylums, and local arrangements for providing skilled evidence in aid of coroners' inquests.

On the present occasion my subject-matter consists so especially of questions of method and organization, that I must here pass without mention many points where the law seems to me in other respects to require amendment; but I may observe in passing, that many of the most important objects which I propose should be matters of quarter-sessions authority are hitherto very imperfectly provided for by law.

D. For certain cases where public health is in question, the central authority is authorized by law to issue orders and regulations which, when issued, have the force of law in relation to the local authorities addressed. And in certain other cases the right of local authorities to take particular courses of action is by law made contingent on the central authority's giving approval to such courses. What ought to be the precise extent of the discretional control to be thus exercised by central authority in local affairs is not a question which needs here be discussed; but the number of cases which statute-law cannot touch in exact terms is so great, that manifestly, if such law is to work with promptitude and ease, it must, to a greater or less extent, be supplemented by that elastic margin of what may be called law in reserve.

Central authority in regard of regulations and sanctions.

E. The ordinary administrative relations which the law supposes to exist between local authorities and central authority in relation to the public health are in substance two:

Ordinary relations between central and local authorities.

first, that the central authority watches the fluctuations of health in all the health-areas of the country respectively;

and, secondly, that, discovering from indications thus supplied the cases where health-law is not properly administered, it takes steps, which in the last resort may be coercive of local authorities, to procure proper obedience to the law.

The extent to which the law imposes definite obligations on local authorities assigns of course a limit to the central authority as regards the class of cases where its coercive interference is possible; but far beyond that limit, as well as also within it, innumerable cases present themselves, where mere information and advice from the central authority may be influences of the utmost value in determining local authorities to right measures for the public health. It is manifest that functions of this sort cannot be exercised by any central authority except in proportion as it is cognizant of local variations in the public health: proper provisions for making all such variations known to the central authority are therefore elementary necessities in that mixed system of central and local government which the law has intended to operate for sanitary purposes in England: and greatly to improve the provisions which now exist in this country for recording and reporting the deaths and sickness of the community, is, in my opinion, an object of quite fundamental importance among such improvements of method as I am considering. The chief points where I think amendment wanted for purposes of general administration are as follows:

a. With regard to the knowledge which ought to be had concerning the deaths of the population, I have three suggestions to make.

Knowledge of deaths to be made available:

First, in my opinion, the law ought as far as practicable to require in every case of death that the cause of the death be medically certified. Exception, not in substance but in form, might have to be made for cases where coroners' inquests are held; *i.e.*, the verdict of any such inquest must of course be understood to include the substance of any required medical certificate. And

medical certificates:

possibly, for very exceptional circumstances, it might be desirable to provide that, in them, any magistrate's order should exonerate from the necessity of the certificate. But, subject only to such qualifications as these, it seems to me that in all cases of death a medical certificate of the cause of death ought to be required; a certificate to be obtained, where practicable, from the medical practitioner who attended the fatal illness; or, where there has been no medical attendant, or none from whom a certificate can be obtained, from the public health-officer of the district.

local distribution:

Secondly, I think it essential that the division of the country for purposes of census and registration of births and deaths should, as far as practicable, treat as separate districts or sub-districts all areas which are separately identified for purposes of health-administration. New special health-areas are constantly in course of formation under the Local Government Act, and perhaps otherwise; and I would suggest that, as soon as possible after the formation of any such special health-district, it should be created a district or sub-district for purposes of registration and census.

statistical returns.

Thirdly, I refer with admiration to the detailed numerical statement which the Registrar General issues every Tuesday on the subject of the deaths of the metropolis during the last preceding week: a statement which relates to three millions of population occupying 137 separate sub-districts, and which not only gives the gross number of deaths for each sub-district respectively, but distinguishes also for each sub-district the more important causes of death; so that persons interested in the health-administration of London are able at a glance to see, with considerable minuteness, in what parts of London each of the principal zymotic diseases has been fatal during the previous week, and what number of deaths in each sub-district each such disease has produced. If what is thus done every week for about a seventh part of the population of England could be done for the whole population, not every week, but every quarter, this quarterly publication would represent one of the most important aids which could be rendered to the health-administration of the country. The present quarterly returns of the Registrar General state what gross number of deaths has occurred in each registration-district of the country; and a few of the sub-district registrars comply with a request which the Registrar General has during some years past made to all of them for "notes" on the prevalence of particular diseases in their sub-districts. But not even an approximative opinion as to the distribution of disease in the country can be formed from these imperfect and uncertain materials; and it is not till nearly two years later that the detailed results of the registration of deaths can be gathered from the annual reports of the Registrar General. A system of quarterly death-reports for the entire country, in general conformity with the weekly death-reports which are given for London, is therefore among the amendments for which I hope.

Knowledge of sickness to be made available.

b. With regard to the knowledge which ought to be had concerning the sickness of the population, I think that, greatly for immediate purposes of medical science and health-administration, and in an even higher degree for common purposes of public

economy, certain broad information ought periodically to be given as to the quantities and kinds of sickness treated by the several destitution-authorities and by the several medical charities of the country. As regards the former, it would seem desirable that at fixed intervals (say quarterly) each destitution-authority should state in a fixed tabular form, for each of its medical relief districts, what numbers of cases of disease generally, and of a few of the more important epidemic diseases individually, had been remaining under treatment at the commencement of the period; and what numbers had been remaining at the end; and what numbers of new cases had come under treatment during the period; and what number of deaths had occurred among new cases and old cases respectively. And as regards medical charities, I venture to suggest that, in the rightly understood interests of their subscribers, no less than for other ends to which I have referred, a system of uniform registration, and an uniform contribution of annual returns, ought to be claimable from them by the central authority, in reference to the sexes, ages, numbers, and kinds of cases treated by them respectively, and to the duration and results of treatment.

Central authority.

F. That any central offices which have to do with sanitary affairs ought, like the local authorities and jurisdictions, to be methodically related to each other and to the public, on some simple consistent plan, according to their respective subject-matters, is of course indisputable: but this section of the argument does not here require at my hands more than a few explanatory remarks. If the present central offices which are more or less concerned in the question be regarded according to their main intentions, and therefore without reference to such minor flaws and uncertainties of jurisdiction as any consolidated law would at once rectify, the following may be taken as their scheme.

Lords of the Council.

a. The functions which my Lords of the Privy Council exercise through their Medical Officer, and for which the Medical Department of the Council Office is constituted under the Public Health Act, 1858, are the essentially sanitary functions of Government: such as the following:

to take practical cognizance of all important faults and fluctuations of the public health, general or local; looking at each such fault or fluctuation as a question of cause and effect, and examining for the common interests whether in each suffering or endangered place everything is done which ought to be done in prevention of the beginnings or spreadings of disease; and thus and from other points of view to act in supervision of all local health-authorities as such, and to give them such advice or to adopt such other measures as the circumstances in each case may shew necessary;

to provide an office of reference and appeal for local authorities and for the people generally on all considerable sanitary influences operating in the country, and on all other public questions of causation and prevention of disease, so far as the knowledge of the time enables such questions to be answered, an office in which scientific knowledge of this sort shall be

systematically gathered and reported for public use, and in which, so far as practicable, such knowledge shall be increased from year to year by special scientific investigations;

to issue, and afterwards to superintend in operation, such orders, regulations and sanctions, as the Government with medical advice sees fit, in relation to various special matters which the Legislature has made subject to this control: as local provision against epidemics, performance of public vaccination, questions as to practice of pharmacy and sale of poisons, questions as to the medical profession, &c.

Home Office.

b. There are two offices which, by a part of their subject-matter, have close, though not extensive, relation to the Medical Department of the Council Office; two offices, namely, which both are under direction of Her Majesty's Home Secretary of State. On the one hand there is the great arithmetical office, over which the Registrar-General presides: the office to which the public looks for all numerical information obtained by periodical census and from local registers, as to the numbers, ages, sexes, birth-places, industries, and family-combinations of the people, and as to the marriages, births and deaths, which take place amongst them: and I need hardly observe that one part of this statistical information constitutes an indispensable basis for some proceedings in the Medical Department. On the other hand, there is the office through which the Secretary of State, under authority of the Local Government Act, controls the exercise of rating and borrowing powers for purposes of local improvement under the Act, and, incidentally to this control, has before him for skilled criticism the various proposals of local authorities for drainage, sewage-utilization, &c. And as this office (essentially including a staff of engineers) has been found the most convenient machinery through which the Secretary of State can advise, and in case of need enforce, in regard of localities, certain constructional improvements which may be needful for the health of the inhabitants, so, in the particular cases where necessities of this sort are in question, the action of Government may be considered as consisting of two stages: the first conducted in this department of the Council Office, and the second conducted in the local improvement office of the Home Secretary. This department then, which is essentially medical, has an important point of contact with each of those two non-medical offices: but the three subject-matters, in their main extent, are necessarily separate for administration. Whether the three offices ought still to remain as now divided under two chief ministers, or might more conveniently be all made subject to one, and, if so, to which one, are questions which of course involve many other considerations than those on which it is my province to enter. I am however permitted to state that these questions, with others relating to the distribution of central sanitary work, are at present being considered by the Ministers whose departments they specially concern.

JOHN SIMON.

APPENDIX.

No. 1.—Statistics of the National Vaccine Establishment, and Educational Vaccinating Stations.

1. Staff at end of 1868.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the purposes of their Lordships' Order of December 1, 1859.

—	Names.	Vaccinating Stations.	Days and Hours of Attendance.
Vaccinators supplying lymph for the public service and salaried from the Parliamentary Grant.	1. Mr. John N. Tomkins, *Inspector.*	Fitzroy Street.	Daily, 10—11.
	2. Mr. J. F. Marson -	*Surrey Chapel.*	Tuesd., Thursd.; 1—2
	3. Mr. G. L. Cooper -	Battle Bridge.	Tuesday; 12—1.
	4. Dr. R. Sharpe -	Bermondsey.	Tuesday; 10—11
	5. Mr. R. Wade -	Dean Street, Soho.	Monday; 9—11.
	6. Mr. A. B. Macann -	King Street, Portman Square.	Monday; 10—11.
	7. Mr. Wm. J. Lewis -	Spital Square.	Monday; 10—11.
	8. Mr. Wm. J. Lewis -	*Wellclose Square.*	Tuesday; 9—11.
	9. Mr. W. E. G. Pearse	*Tottenham Court Chapel.*	Mond., Wednesd.; 1–2
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	1. Mr. Ellis S. Guest -	*Manchester.*	Monday; 2—4.
	2. Dr. G. F. De la Cour	*Birmingham.*	Monday; 10—12.
	3. Dr. H. A. P. Robertson	*Bristol.*	Tuesday; 11—12.
	4. Mr. A. B. Steele - / Mr. J. H. Wilson - / Mr. John Fenton -	*Liverpool.*	Monday; 9. / Friday; 2.
	5. Dr. E. L. Webb -	*Pimlico.*	Monday; 10—12.
	6. Mr. G. C. Gilchrist -	*Newcastle-on-Tyne.*	Tuesday; 2—3.
	7. Mr. W. E. G. Pearse	*Westminster.*	Monday; 9—11.
	8. Mr. J. G. Gerrans -	*Marylebone.*	Monday; 10—11.
	9. Mr. Frederick Holmes	*Leeds.*	Tuesday; 3¼.
	10. Dr. Edward Lynes -	Coventry.	Monday; 12—2.
	11. Mr. Joseph Teale -	Salford.	Thursday; 2½.
	12. Dr. James Dunlop -	*Glasgow.*	Monday; 12—1.
	13. Mr. C. Harriot Roper	*Exeter*	Thursday; 3.
Teachers of Vaccination not supplying lymph.	1. Mr. Robt. W. Dunn	*Strand.*	Monday; 10.
	2. Dr. W. Husband -	*Edinburgh* -	Wed., Sat.; 12.

APPENDIX.

No. 1.
Statistics of the National Vaccine Establishment, and Educational Vaccinating Stations.

Statistics of the National Vaccine Establishment and Educational Vaccinating Stations—*continued.*

2. SOURCES and AMOUNT of LYMPH SUPPLY in 1868.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the Purposes of their Lordships' Order of December 1, 1859.

—	Vaccinating Stations.	No. of Vaccinations performed at the Stations respectively.		No. of charges of Lymph supplied from the Stations respectively.	Remarks.
		Prim^s	Re-vac^ns		
Vaccinators salaried from the Parliamentary Grant.	1. Fitzroy Street	783	—	4,750	
	2. *Surrey Chapel*	1,252	35	15,750	
	3. Battle Bridge	472	—	5,388	
	4. Bermondsey	748	39	11,078	
	5. Dean Street, Soho	491	13	8,730	
	6. King Street, Portman Square	309	5	5,845	
	7. Spital Square	307	—	9,586	
	8. *Tottenham Court Chapel*	896	20	16,218	
	9. *Wellclose Square*	305	—	9,066	
Total	9 Stations	5,563	112	86,411	
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	1. *Manchester*	1,395	—	18,387	
	2. *Birmingham*	1,197	4	5,520	
	3. *Bristol*	527	—	3,812	
	4. *Liverpool*	904	—	17,643	
	5. *Pimlico*	879	8	34,524	
	6. *Newcastle-on-Tyne*	333	1	6,106	
	7. *Westminster*	782	10	16,378	
	8. *Marylebone*	670	38	4,823	
	9. *Leeds*	748	—	18,733	
	10. Coventry	721	—	847	
	11. Salford	1,131	—	7,040	
	12. *Glasgow*	1,079	—	6,601	
	13. *Exeter*	—	—	—	
Total	13 Stations	10,356	61	140,414	
General Total	22 Stations	15,919	173	226,825	

Statistics of the National Vaccine Establishment and Educational Vaccinating Stations—*continued.*

AMOUNT of LYMPH SUPPLY.

3. SUMMARY for the Years 1856–1868.

Year.	Total Vaccinations performed at the Stations which supply Lymph.	Re-vaccinations included in preceding Column.	Number of Charges of Lymph supplied.
1856 - -	7,039	?	210,942
1857 - -	6,327	?	213,207
1858 - -	6,445	?	234,150
1859 - -	9,030	?	237,801
1860 - -	13,849	?	228,347
1861 - -	12,009	?	225,000
1862 - -	13,149	?	211,475
1863 - -	20,600	?	239,432
1864 - -	13,727	?	203,250
1865 - -	14,648	515	219,832
1866 - -	14,319	372	207,014
1867 - -	14,911	584	216,637
1868 - -	16,092	173	226,825

APPENDIX.

No. 2.
Further Vaccination Regulations.

No. 2.—FURTHER REGULATIONS by the LORDS of the COUNCIL for securing the efficient performance of PUBLIC VACCINATION, and in respect of the RE-VACCINATION of persons who apply to be re-vaccinated, made and issued February 18th, 1868.

I.—*Places and Times for Vaccination under Contract.*

Public Vaccinator, under ordinary circumstances, to vaccinate only at public Stations;

1. Except where the Privy Council, for reasons brought to its notice, sees fit in regard of any particular district to sanction a system of domiciliary vaccination, every vaccination-district shall have in it at least one public station appointed for the performance of the vaccinations under contract; and where any such station has been provided for a district, no person resident within two miles thereof, and not being an inmate of the workhouse, shall be vaccinated under contract elsewhere than at such station, unless the vaccinator in the particular case be of opinion (which, if so, he is hereby required to note in his register) that, for some special reason, the person whom he purposes to vaccinate cannot properly be vaccinated at the station.

and not oftener than once weekly;

2. Except under special authorization from the Privy Council as aforesaid, or in so far as may be expedient at times when there is immediate danger of small-pox, vaccination under contract shall not be appointed to be performed at any station oftener than once a week.

and, if in a town-district, only at one Station therein.

3. And in any future contract concerning a vaccination district which is partly or wholly within a town, there shall not, except under special authorization as aforesaid, be appointed within the town more than a single station for the performance of the vaccinations of the district.

II.—*Vaccination Districts in Towns.*

Limitation as regards Towns, on the Smallness of Districts for Vaccination.

No part of the metropolis, or of any city, or municipal borough, or town corporate, or other town, shall, in respect of any future contract, form by itself, or with any rural place, a separate district for vaccination, except with the approval of the Privy Council, unless it contain an estimated population of at least 25,000 persons, or else be as much of the metropolis, city, borough, or town, as is for purposes of vaccination under the control of one board of guardians.

III.—*Office of Public Vaccinator.*

Each District to have its own Public Vaccinator.

After the expiration of the month of June next, no two or more persons shall be allowed to act severally as vaccinators under contract in any one and the same part or district of any union or parish.

IV.—*Re-Vaccination.*

Extent to which Re-Vaccination at public expense may be given.

The performance of re-vaccination by the public vaccinator on persons applying to him for that purpose shall be limited in each case by the following conditions: (1) that, so far as the public vaccinator can ascertain, the applicant has attained the age of 15 years, or, if during any immediate danger of small-pox, the age of 12 years, and has not before been successfully re-vaccinated; and (2) that, in the public vaccinator's judgment, the proposed re-vaccination is not for any sufficient medical reason undesirable; and (3) that the public vaccinator can afford vaccine lymph for the purpose without in any degree postponing the claims which are made on him for the performance of primary vaccination in his district.

No. 3.—REPORT by Dr. EDWARD BALLARD, Medical Officer of Health for Islington, on the RESULTS of an ANALYSIS of RECORDS of SICKNESS kept in ISLINGTON during the 12 years 1857 to 1868 inclusive.

THE 26 diagrams represent the fluctuations, week by week, of the more important elements of weather during a period of 12 years, namely from 1857 to 1868, inclusive, together with the variations in the amount of general sickness, and of certain important special forms of sickness, as obtained from records of new cases of disease admitted for treatment in certain institutions where the sick poor are treated in the parish of St. Mary, Islington. The record of weather employed in the construction of the diagrams is that published in the weekly returns of the Registrar General. The parish of Islington is one of the most rapidly increasing parishes in the metropolis. In 1851 the population amounted to 95,329 persons; in 1868 it could not be calculated at less than 200,000. This rapid increase must be taken into account by anyone comparing the diagrams of one year with those of another. The diagrams for the first three years, again, are constructed from the records of the parochial workhouse, and the infant poorhouse, together with those kept by eight medical officers attending sick paupers out of doors, and at the Holloway Dispensary. In 1860 the Islington Dispensary began to keep a record of their new cases of sickness, and from that year forward this institution is included in the diagrams. Beside the variations in the admissions of new cases of sickness generally, I have marked those of respiratory diseases (bronchitis and catarrh, pneumonia and pleurisy), of diarrhœal affections, and of the four common epidemic diseases, small pox, measles, scarlatina, and hooping cough. Diagrams 25 and 26 are of the nature of a *summary* of the twelve years, representing the average weather of each week and the average number of cases of sickness received in each week under treatment. They exhibit the average prevalence of sickness at the different seasons of the year (as deduced from the 12 years' observations), and also that of the several common affections particularized. The total number of cases tabulated for the purpose of these diagrams is as follows:—

Of general sickness -	272,469	cases.		
Of respiratory diseases -	47,889	„	=175·7	per 1,000 of all cases.
Of diarrhœal affections -	16,456	„	= 60·3	„ „
Of measles - -	5,501	„	= 20·1	„ „
Of hooping cough -	4,580	„	= 16·8	„ „
Of scarlatina - -	3,850	„	= 14·1	„ „
Of small pox - -	1,97	„	= 7·2	„ „

This table indicates *the order of frequency of occurrence* of these diseases in an average town population, during a period sufficiently prolonged to afford time for the occurrence of several epidemics of each, varying in their degree of severity. It is not the same order as comes out when the deaths occurring in the same period are added up. The deaths among all classes of the resident population in the parish of Islington during the same 12 years were as follows:—

		Per 1,000 of all deaths.
Deaths from all causes - - -	40,071.	
„ respiratory diseases - -	7,138	=178·1
„ scarlatina - - - -	2,007	= 50·0
„ diarrhœal affections - -	1,971	= 49·1
„ hooping cough - - -	1,756	= 43·8
„ measles - - - -	1,142	= 28·4
„ small pox - - - -	475	= 11·8

The comparatively small fatality of small pox and measles, and the comparatively very high fatality of hooping cough, and especially of scarlatina, are obvious on a comparison of these two tables. Unfortunately, too, although these latter diseases do not stand high in the list of epidemic maladies for frequency of occurrence, they not only are of high immediate fatality, but by the damage they effect to the lungs and kidneys respectively, they lay the foundation for chronic affections which go ultimately to swell the catalogue of premature deaths.

GENERAL SICKNESS.

The total number of cases of sickness generally, observed during the 12 years, was 272,469. They were thus distributed:—

In 1857	12,796 cases.	In 1863	26,710 cases.
1858	13,836 „	1864	23,951 „
1859	15,086 „	1865	23,447 „
1860	21,842 „	1866	27,450 „
1861	23,326 „	1867	27,365 „
1862	23,929 „	1868	32,731 „

Diagrams 25, 26, exhibit the line of general sickness as it was, on the whole, distributed through the several periods of the year. The diagrams 1 to 24 exhibit the same line for each year of the twelve. It is to be observed that it forms two waves. Commencing from the 22d week in the year (the 1st week in June), when the general sickness was on the whole at its minimum, the first wave rises rapidly to attain its maximum in the 33d week (the 3d week in August); it then descends still more rapidly than it rose during the next four weeks, terminating in the 37th week (the 2d week in September), but with an amount of sickness considerably greater than that with which it commenced. This wave only occupies 15 weeks out of the 52 for its completion. The remaining 37 weeks are occupied with the second and larger wave, which quickly attains its maximum elevation in the 47th week, and thence declines gradually through the winter, and notably through the spring, until it ends in the minimum of the year again in the 22d week.

There is a fallacy to be taken into account in respect of the sickness recorded in December, especially at its close, and in that of the first week of January, which renders the amount of sickness apparently less than in all probability it actually was. I allude to the social and domestic occupations of the people at this season, culminating in the Christmas week, which very evidently deters them from the seeking of medical advice for lesser ailments, such as would at any other time have sent them to the union surgeons or dispensaries. There is observed thus a gradual diminution in the number of new cases week after week as soon as November has closed. The weekly average of new sickness in the last week of November being 470 cases, it fell week by week as follows:—

48th week	463 cases.
49th „	459 „
50th „	459 „
51st „	387 „
52nd „	321 „
1st week Jan.	426 „

Hence, instead of taking the actual returns of sickness for December as indicating the line of sickness at that period of the year, it would be more accurate to supplant them by the mean of the sickness of November and January. Making such a correction we find that, taking the whole sickness of the year as 1,000, the cases are distributed through the several months as follows:—

January	84·1 cases	Winter quarter	248·5	cases.
February	82·6 „			
March	81·8 „			
April	80·3 „	Spring quarter	237·8	„
May	78·4 „			
June	79·1 „			
July	85·4 „	Summer quarter	257·7	„
August	88·7 „			
September	83·6 „			
October	84·2 „	Autumn quarter	256·0	„
November	86·5 „			
December	85·3 „			
	1,000·0 cases.		1,000·0	cases.

Hence the experience of our 12 years in Islington has been on the whole that, of the several quarters of the year, the summer has been the most sickly, the autumn rather less so, but nearly equalling it; that next in order comes the winter quarter, and that the spring quarter has been the least sickly of all.

Of the several months of the year, the order of sickliness has been, August the most sickly, then November, July and December, January and October, September, February, March, April, June, and May, the last being the most healthy month of the year.

Diagram No. 25 shows the relation borne by the line of annual sickness to the average meteorological conditions of the several seasons of the year. The minimum of sickness corresponds with a season at which the mean temperature of the air is just 58·7°, with a mean daily range of about 21 degrees, the mean atmospheric humidity being 76 (saturation 100), with an average rainfall of 0·82 inches, distributed over between two and three days in the week. From this point it is observable that the sickness rises as the warmth of the air rises and the daily range of temperature increases towards the summer months, these conditions being associated with lessened rainfall and greater dryness of the air. But it is further to be noticed, that the summit of the summer wave of sickness is not attained until some four or five weeks after the maximum temperature of the year has been reached, and until a time when the summer heat is in course of subsidence, the daily range lessening and the rainfall and atmospheric moisture becoming greater. The end of the summer wave (the minimum of summer sickness) corresponds with a time when the mean temperature is the same as at the spring minimum of sickness, viz. 58·7°, the daily range of temperature being about 16 degrees, the atmospheric humidity about 78, with a rainfall of 0·50 inch distributed over between two and three days in the week. Comparing the smaller spring minimum with the greater summer minimum of sickness, we may observe that while the mean temperature is about the same at the two periods, the former corresponds with a greater daily range, more rainfall, and rather less atmospheric humidity than the latter. So much for the summer wave.

The greater wave of sickness, which is to occupy the autumn, winter,

and part of the spring, begins to rise as the mean temperature of the year sinks below 58·7°, as the daily range continues to lessen, and as, with these conditions, the atmospheric humidity increases above 78. The maximum sickness is, as has been observed, quickly attained; the summit of the wave corresponds to a temperature of 41·2°, with a daily range of about 11 degrees, and a relative atmospheric humidity of 88. This wave subsides (unlike the summer wave) very gradually indeed; it is not peaked like the summer wave, but has a broad summit, very little subsidence occurring until the seventh week of the winter quarter. Still, during these weeks, from the 47th week of the year onwards, a slight subsidence is observed, corresponding to the slight increase of temperature and the slow reduction in the humidity of the atmosphere which takes place in the last few weeks of December and the beginning of the year. The imperfection of the records of sickness (before alluded to) in the last weeks of December and the first week of January interferes with the determination of the influence of the greatest cold in the first week of the year. However, it is clear that the gradual reduction in the general sickness, and most marked subsidence of the large wave, follow almost immediately upon a rise of the mean temperature above 40°, with diminution of the humidity of the air below 84; and that they continue as the temperature of the year increases, the daily range becomes greater, and the atmospheric humidity less and less.

In looking at the diagrams one is struck forcibly with the facts, 1°, of the excessive sickliness of the year 1863; 2°, of that of the cholera year 1866, from the month of February onwards, not merely of the summer quarter, which would be explicable from the existence of the epidemic; and, 3°, of the continued extraordinary sickliness of the two years succeeding the cholera epidemic, a sickliness not confined to any one quarter, but extending to all the seasons. There is nothing in common in the ordinary meteorological circumstances of these four years to account for these facts. 1863 and 1868 agreed to a certain extent, in having on the whole a high temperature and in being comparatively dry, but 1866 and 1867 were comparatively cool and wet. 1863 was in all respects a remarkable year as regards sickness; for not only was the general sickness high, but it was the year of the grand outburst of small-pox, as well as of a serious epidemic of scarlatina, hooping cough being also unusually prevalent. The year 1866 was notorious not only for the cholera outbreak, but also for a severe epidemic of measles and a renewal of the small-pox epidemic. The year 1867 was remarkable also for the great prevalence of small-pox and scarlatina, and 1868 for scarlatina, measles, and hooping cough. The high sickliness of the year 1863 is in great measure explicable by the wide-spread distress arising out of the cotton famine, and 1867 and 1868 were years of greatly depressed trade, and in addition 1868 was a year in which the price of provisions was exceedingly high.

The order of sickliness of the several quarters and months, as deduced from a general view of my experience of the past 12 years, was not, of course, observed every year. During the 12 years—

Summer	stood	highest	in the	order of	sickliness	6 times.
,,	,,	second	,,	,,	4	,,
,,	,,	third	,,	,,	1	,,
,,	,,	fourth	,,	,,	1	,,
Autumn	,,	highest	,,	,,	3	,,
,,	,,	second	,,	,,	3	,,
,,	,,	third	,,	,,	4	,,
,,	,,	fourth	,,	,,	2	,,

Winter	stood	highest	in the order of sickliness	twice.	
„	„	second	„ „	5	times.
„	„	third	„ „	2	„
„	„	fourth	„ „	3	„
Spring	„	highest	„ „	1	„
„	„	second	„ „	1	„
„	„	third	„ „	4	„
„	„	fourth	„ „	6	„

The most uniformly sickly quarter, then, has been the summer, and the most uniformly healthy quarter has been spring. Autumn would probably come out more uniformly high in sickliness, but for the fallacy introduced by its embracing the month of December.

The meteorological conditions which appear to exercise the most decided influence upon the quantity of general sickness are atmospheric temperature and humidity and rainfall. Table I. is constructed with a view to show what these conditions were in the quarters of greater and less sickliness. I have also introduced columns showing the average cost of provisions in each quarter, and the average amount of pauperism. I have excluded the years 1863, 1867, and 1868, as calculated to disturb the general result. (See Table I., pp. 42, 43.)

From this table it appears, 1st. That the mean temperature of the most sickly quarters, whether winter, spring, summer, or autumn, was on the whole higher than that of the less sickly quarters. This difference is most obvious in the winter quarter, next in the summer quarter, and least in the spring quarter.

2d. That in the winter and spring the mean humidity of the atmosphere was on the whole less in the more sickly quarters than in the less sickly. In the summer and autumn quarters this difference is not remarkable.

3d. That the rainfall (including snow) was greater in the more sickly than in the more healthy winters. In the summers there was scarcely any difference in the mean rainfall of the sickly and more healthy quarters. In the spring and autumn the more healthy quarters were remarkable on the whole for a greater rainfall than the more sickly ones.

4th. That rain fell more frequently in the more sickly winters and summers than in the more healthy ones, but much less frequently in the more sickly than in the more healthy spring quarters.

On the whole it would appear that atmospheric temperature is the most important of the meteorological conditions mentioned, which influence the amount of general sickness. That in the winter a comparatively high temperature with atmospheric dryness, and much and frequent rain or snow, is calculated to render the season unhealthy; and conversely, that cold weather, with a moister atmosphere, and comparatively little rain and snow, is calculated to render the season healthy. That in the spring a moist atmosphere, with frequent and abundant rain, together with comparative lowness of temperature, is calculated to impart a healthy character to the season, while warmer and drier springs are on the whole less healthy. That in the summer season the healthiness or unhealthiness depend almost wholly upon the temperature. Lastly, that the healthiness or unhealthiness of the autumn also depends more upon its temperature than upon any other meteorological condition.

The exceptional year 1863, each quarter of which was unusually sickly, was remarkable for the comparatively high temperature of the winter and autumn quarters, and the atmospheric dryness of the whole year.

TABLE I.

WINTER QUARTERS.

Of greater Prevalence of Sickness.

Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.
		°				s. d.	d.	d.	
1859	4,004	43·3	83	2·55	33	40 8	5¾	5⅞	865,818
1860	6,640	38·9	82	3·80	52	44 5	5⅛	5¾	835,787
1862	6,118	40·6	86	5·73	43	60 1	5⅛	5⅝	948,198
1864	6,174	38·2	82	4·27	37	40 4	5⅛	6¼	995,334
1866	6,599	41·2	83	9·55	51	45 6	5⅜	6⅝	898,948
Mean -	5,907	40·4	83	5·18	43·2	46 2	5⅜	6	908,817

Of less Prevalence of Sickness.

Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.
		°				s. d.	d.	d.	
1857	3,167	36·3	85	3·79	35	56 10	5¾	6¼	912,547
1858	2,998	37·9	81	3·41	20	46 5	5¼	5⅞	974,017
1861	5,689	39·7	89	4·96	40	55 1	6	7¼	889,942
1865	5,780	36·6	82	5·94	45	38 4	5¾	6¼	955,700
Mean -	4,408	37·6	84	4·52	35·0	49 2	5¾	6⅜	933,051

SPRING QUARTERS.

Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.
1859	3,599	54·2	77	6·40	29	47 3	5⅝	5⅞	819,560
1861	5,619	51·6	81	4·73	30	54 9	5⅝	6¼	831,587
1864	5,916	53·5	73	3·48	22	39 7	5¼	6⅛	908,542
1865	5,937	56·3	72	7·24	24	40 6	5¾	7⅜	901,862
1866	6,411	52·9	75	8·00	35	46 6	5⅞	7	857,796
Mean -	5,476	53·7	76	5·97	28·0	45 8	5⅓	6½	863,869

Of less Prevalence of Sickness.

Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.
1857	2,889	54·3	76	4·06	31	56 9	5⅝	5¾	851,525
1858	3,287	54·7	72	5·07	30	44 1	5⅓	5⅓	871,512
1860	5,112	50·5	80	10·36	49	52 8	5¾	6½	799,434
1862	5,552	53·1	82	7·61	46	56 8	5	6	909,721
Mean -	4,210	53·1	77	6·77	39	52 6	5¼	5¾	858,048

TABLE I.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Sickness.										Of less Prevalence of Sickness.									
Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.	Years.	New Cases of Sickness.	Mean Temperature.	Mean Humidity.	Rain in Inches.	Rainy Days.	Price of Wheat.	Price of Beef.	Price of Mutton.	Pauperism.
		°				s. d.	d.	d.				°				s. d.	d.	d.	
1857	3,610	63·3	77	5·73	30	59 11	$5\frac{3}{8}$	$5\frac{3}{4}$	812,015	1858	3,514	61·0	74	5·39	29	44 7	$5\frac{1}{4}$	$5\frac{1}{2}$	812,498
1859	4,133	62·8	73	7·10	33	44 0	$5\frac{1}{4}$	$5\frac{3}{4}$	783,449	1860	4,785	56·3	85	9·12	52	59 1	$5\frac{5}{8}$	$6\frac{3}{8}$	769,360
1861	6,269	60·4	78	4·20	43	52 1	$5\frac{3}{8}$	$5\frac{7}{8}$	805,581	1862	3,838	60·2	81	5·75	33	56 10	$5\frac{1}{2}$	$6\frac{1}{4}$	909,506
1866	7,841	58·7	80	7·93	45	51 0	$6\frac{1}{8}$	$6\frac{3}{4}$	838,508	1864	5,932	59·4	71	4·37	24	42 3	$5\frac{1}{2}$	$6\frac{1}{4}$	855,039
										1865	5,907	62·5	75	6·41	29	43 3	$5\frac{3}{4}$	$7\frac{1}{2}$	836,761
Mean-	5,463	61·3	77	6·24	37·7	51 9	$5\frac{1}{2}$	6	809,888	Mean-	5,195	59·9	77	6·20	33·4	49 2	$5\frac{1}{2}$	$6\frac{1}{4}$	836,632

AUTUMN QUARTERS.

1858	4,037	43·5	87	3·11	31	41 9	$5\frac{1}{4}$	$5\frac{1}{2}$	826,655	1857	3,130	47·4	92	5·56	23	52 0	$5\frac{3}{8}$	$5\frac{3}{4}$	859,756
1861	5,749	46·4	88	7·23	35	59 3	$5\frac{1}{8}$	$5\frac{3}{4}$	844,429	1860	5,305	42·8	89	4·59	35	56 9	$4\frac{7}{8}$	$5\frac{3}{4}$	788,838
1862	6,421	45·6	89	7·04	40	48 2	$5\frac{1}{8}$	6	1,040,156	1859	3,350	43·0	87	7·18	48	43 4	$5\frac{1}{4}$	$5\frac{3}{4}$	793,391
1866	6,599	46·5	87	5·36	41	56 8	$5\frac{7}{8}$	$6\frac{3}{8}$	868,291	1864	5,929	43·6	82	4·13	29	38 5	$5\frac{6}{8}$	$6\frac{1}{4}$	900,201
										1865	5,823	46·1	88	8·92	46	44 10	$5\frac{5}{8}$	$6\frac{7}{8}$	854,295
Mean-	5,701	45·5	88	5·68	36·7	51 5	$5\frac{1}{4}$	$5\frac{7}{8}$	894,882	Mean-	4,707	44.6	88	6·07	36·2	47 0	$5\frac{1}{4}$	6	839,296

In 1867 the sickly winter was cold and comparatively dry, the spring after April had closed warm, the summer not hot until towards its close, and the autumn comparatively cold.

Last year, which was without parallel for sickliness in all the 12, was without parallel also for its uniformly high temperature, little rainfall, and atmospheric dryness. It was only in the latter part of October and in November that the mean temperature fell for any number of consecutive weeks below the average of the season. The average price of wheat was 72*s.* in the winter, 61*s.* in the spring, and 59*s.* in the summer; trade was depressed and pauperism excessive. No wonder, with this accumulation of causes, that the sickness of the year was so great.

The fluctuations of general sickness from week to week are mainly dependent upon the variations of temperature and the occurrence of drought or rainfall. An examination of the diagrams will show that commonly a rise of mean temperature in any week above that of the previous week is associated with an increase of general sickness, while a fall of mean temperature is commonly associated with a reduction in the quantity of general sickness. The greater the extent of these rises and falls the more certain on the whole is the occurrence of the associated normal alteration in amount of sickness. This variation of sickness with fluctuations in temperature is more decided in the colder than in the warmer seasons of the year. It is a subject which I have discussed so fully elsewhere (Med. Chir. Trans., vols. l. and li.), that I need say no more about it here. There are, however, two periods of the year when the rule ceases to apply. One of these is in the spring of the year, when the mean temperature begins permanently to rise above 40°, and the other in the end of the summer, when the temperature usually falls with more or less rapidity below 59°, with considerable increase in the atmospheric humidity. With respect to drought and rainfall, the examination of the diagrams seems to show that, whatever their operation may be on the whole upon the absolute amount of sickness, the first effect of rainfall is to reduce the number of new applicants for relief of sickness, and of absence of rain to increase their number. On analysing tables which I have constructed for the seven years, 1859 to 1865, I find that increase of sickness apparently occurred in 61 per cent. of the weeks in which there happened an entire absence of rainfall; that in weeks in which less than half an inch of rain fell decrease of sickness occurred in only 46 per cent., in weeks in which half an inch and less than one inch fell decrease of sickness happened in 53 per cent., and when more than one inch fell decrease of sickness happened in 61 per cent. The absence of rain and the occurrence of rain both operated more effectually in their several directions when associated with a fall of mean temperature than when associated with a rise.

Diseases of the Organs of Respiration.

Under this term I have grouped together bronchitic and catarrhal affections, asthma, pneumonia, and pleurisy. Not but that the meteorological conditions promotive of these several kinds of attack may be different, but because in the kind of practice from which the data of sickness are taken I find that some of them are not clearly distinguished from others. This is especially the case with the inflammatory diseases of the chest in infants. I exclude phthisis.

The total number of cases of respiratory disease recorded during the

12 years is 47,857. They were distributed among the several years as follows:—

In 1857	- 2,490	cases, or	19·4	per cent.	of all cases.
„ 1858	- 2,903	„	20·9	„	„
„ 1859	- 2,520	„	16·7	„	„
„ 1860	- 4,043	„	18·5	„	„
„ 1861	- 3,331	„	14·2	„	„
„ 1862	- 3,999	„	16·7	„	„
„ 1863	- 4,439	„	16·6	„	„
„ 1864	- 4,128	„	17·1	„	„
„ 1865	- 4,088	„	17·4	„	„
„ 1866	- 4,771	„	17·3	„	„
„ 1867	- 5,346	„	19·5	„	„
„ 1868	- 5,799	„	17·7	„	„

As regards the distribution of these diseases on the average throughout the year, it is observable on Diagram 25 that they form one wave, which rises rapidly from the end of the summer during a few weeks, and after attaining its climax subsides through the winter and spring with remarkable deliberation. The following exhibits the distribution of these diseases through the several months and quarters per 100 cases on the average of the 12 years:—

In January	- 12·8	Winter quarter	- 34·1	cases.
„ February	- 10·9			
„ March -	- 10·4			
„ April -	- 8·6	Spring quarter	- 20·4	„
„ May -	- 6·5			
„ June -	- 5·3			
„ July -	- 4·2	Summer quarter	- 13·5	„
„ August	- 4·0			
„ September	- 5·3			
„ October	- 8·9	Autumn quarter	- 32·0	„
„ November	- 12·2			
„ December	- 10·9			
	100·0		100·0	

It is certain that 10·9 per cent. do not represent the full proportion of December cases, on account of the fallacy previously alluded to. Probably the December cases, if the necessary correction were made, would be equally numerous with the January cases, and thus the autumn would come at least to equal the winter quarter in the prevalence of this class of maladies. It will, therefore, be a fair statement to make that these diseases are at the lowest ebb in the months of July and August; that they begin to prevail in the month of October, and attain their maximum of prevalence in December or January; and then that a gradual, slow, but regular decline takes place through the succeeding months of winter and spring. On the average of the 12 years, the largest number of cases was recorded in the second week of January, and the smallest in the first week in August.

On looking at Diagram 25, it will be observed how very closely the line of general sickness follows that of the respiratory diseases through the year. The correspondence would apparently be almost complete, were it not for the disturbance occasioned by the cropping up of diarrhœal affections in the later spring and in the summer months. It

is this disturbance which evidently occasions the small summer wave in the line of general sickness. The natural inference is, that the quantity of general sickness is chiefly dependent upon the quantity of respiratory disease prevalent at any time, except in the summer season.

I must observe, however, further, that the subsidence of respiratory sickness during the first two or three weeks of December is too great to be attributable to the social cause which lessens the number of new applicants for medical relief during the last weeks of that month, and it is apparently more closely connected with a habitual meteorological condition in these weeks which I shall allude to presently.

Comparing the line of respiratory diseases in Diagram 25 with the meteorological conditions indicated on the table, what strikes us most is the fact that it is almost the precise reverse of the line of mean temperature. It is true that the lines indicate that respiratory diseases are not at their minimum precisely at the time that the highest temperature of the year is attained, nor at their maximum precisely at the time that the lowest temperature is reached; in the former case the minimum is late by about three or four weeks, in the latter the maximum is late by about one week. But this only corresponds with what has been previously remarked about the greater readiness with which these maladies increase among the population than that with which they diminish. Looking for the reason of this general fact, it is difficult to disconnect it with the great difference in the character of the autumn and winter and spring as respects atmospheric humidity, as well as the greater rapidity with which the mean temperature falls from the summer during the autumn than that with which it rises from January to July. The autumn is quite unique in this respect, for not only does the humidity increase most rapidly during September and October, but the humidity of the autumn altogether is very much higher than that of the winter season. Hence it is, probably, that for the same mean temperatures there is in the autumn a larger quantity of respiratory disease than in the winter. Contrast, for instance, the months of November and March. Again, the second week in January was on the whole the most humid week of the whole winter, not the coldest week; and the first week in August was the least humid week of the summer, not the warmest.

I may now refer to the fall in the amount of respiratory diseases, observed in the average of years to occur in the first two or three weeks of December. During the first half or two-thirds of the autumn respiratory diseases were noticed to increase rapidly, and to attain a maximum of prevalence in the last week of November, the 47th week of the year, the mean temperature being 41·2°, and the mean humidity of the air 88. During the next two weeks a mean rise of a degree or a degree and a half of temperature was observed, and although with this the mean humidity was the same or higher, a smaller quantity of respiratory disease occurred on the whole in these weeks.

Table II. shows, for each quarter, the mean meteorological conditions existent in years in which diseases of this class were more or less prevalent. The teaching of the table is not to be mistaken, since it shows for each quarter or season of the year that the occurrence of diseases of this class is promoted by a comparatively low temperature for the season, a comparatively high atmospheric humidity, and much and frequent rain. The only apparent exceptions are, that in the winter quarters the atmospheric humidity was on the whole greater in those years in which respiratory diseases were less prevalent at this season, and that in the autumn there was rather more rain in the years

in which the respiratory diseases prevailed, less than in those in which they were more prevalent. (See Table II., pp. 48, 49.)

Sickness of this kind appears from the diagrams to fluctuate from week to week, increasing in weeks of rise, and decreasing in weeks of fall, of mean temperature. This relation to fluctuations of temperature is very strikingly exemplified in some of the diagrams, and is much more obvious in the colder than in the warmer months. Somewhere about the commencement of the second quarter of the year, when the mean temperature rises permanently above 45°, or thereabouts, this relation ceases for a time to be observable, and rises of mean temperature come to be immediately associated with diminution of respiratory sickness. Also, towards the close of the summer quarter, a similar exceptional occurrence is observed, when the mean temperature falls in the progress of the year below 60°, or thereabouts; at this time, instead of the falls of temperature being associated with diminution, each weekly reduction of temperature is for a time associated with an increase of respiratory sickness. The exact temperature at which this event is met with varies from year to year; when the summer has been hot it appears to occur at a higher mean temperature than when the previous summer has been cool. Contrast, for example, the lines of temperature and respiratory sickness towards the end of the summer season in 1868 with those in 1860 or 1862.

Diarrhœal Affections.

The affections thus grouped together are, ordinary diarrhœa, so-called dysentery, and ordinary summer cholera. Of these affections 16,456 cases have been recorded during the 12 years. They were thus distributed:—

In 1857	-	1,375	cases, or	10·7	per cent.	of all cases.
„ 1858	-	868	„	6·3	„	„
„ 1859	-	1,322	„	8·7	„	„
„ 1860	-	721	„	3·3	„	„
„ 1861	-	1,395	„	5·9	„	„
„ 1862	-	950	„	3·9	„	„
„ 1863	-	1,340	„	5·0	„	„
„ 1864	-	1,205	„	5·0	„	„
„ 1865	-	1,325	„	5·6	„	„
„ 1866	-	2,586	„	9·4	„	„
„ 1867	-	1,341	„	4·9	„	„
„ 1868	-	2,028	„	6·1	„	„

For the most part then in the years in which respiratory diseases have been proportionally to all sickness less prevalent, diarrhœal affections have been more prevalent. The years 1863, 1866, and 1868 were years in which, however, both respiratory diseases and diarrhœal affections, together with the general sickness, gave high numbers.

The Diagram 25 shows that although diarrhœal affections are met with in practice all the year round, yet the cases only become abundant as the spring draws to a close, during the summer, and the early part of the autumn. Still the following monthly statement of the prevalence of these affections on the mean of 12 years shows that there is a regular wave commencing from the coldest season of the year, rising pretty steadily, but very gradually, to the middle of spring, when the rapidity of increase becomes greater, almost week by week, until the summit of the wave is attained. In like manner these affections diminish rapidly at first, but after about the middle of autumn slowly and steadily to a

TABLE II.—RESPIRATORY DISEASES.

WINTER QUARTERS.

Of greater Prevalence of Respiratory Diseases.						Of less Prevalence of Respiratory Diseases.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1860	1,611	38·9	82	3·80	52	1857	782	36·3	85	3·79	35
1863	1,447	42·5	83	4·08	35	1858	925	37·9	81	3·41	20
1864	1,518	38·2	82	4·27	37	1859	946	43·3	83	2·55	33
1865	1,450	36·6	82	5·94	45	1861	1,098	39·7	89	4·96	40
1866	1,586	41·2	83	9·55	51	1862	1,307	40·6	86	5·73	43
1867	2,002	38·5	83	6·29	51	1868	1,560	41·1	82	6·52	46
Mean -	1,602	39·3	83	5·66	45	Mean -	1,103	39·8	85	4·49	36

SPRING QUARTERS.

1859	554	54·2	77	6·40	29	1857	385	54·3	76	4·06	31
1860	791	50·5	80	10·36	49	1858	466	54·7	72	5·07	30
1863	922	52·6	77	5·99	34	1861	674	51·6	81	4·73	30
1866	1,115	52·9	75	8·00	35	1862	779	53·1	82	7·61	46
1868	1,385	55·1	74	4·22	21	1864	806	53·5	73	3·48	22
						1865	841	56·3	72	7·24	24
						1867	919	54·3	77	6·27	39
Mean -	953	53·1	77	6·99	33	Mean -	695	54·0	76	5·49	31

TABLE II.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Respiratory Diseases.						Of less Prevalence of Respiratory Diseases.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1860	534	56·3	85	9·12	52	1857	359	63·3	77	5·73	30
1862	613	60·2	81	5·75	33	1858	342	61·0	74	5·39	29
1863	706	59·1	74	5·18	27	1859	310	62·8	73	7·10	33
1866	652	58·7	80	7·93	45	1861	505	60·4	78	4·20	43
1867	666	59·7	78	11·40	35	1864	512	59·4	71	4·37	24
1868	920	64·1	70	4·40	23	1865	504	62·5	75	6·41	29
Mean -	681	59·7	78	7·29	35	Mean -	422	61·6	75	5·53	31

AUTUMN QUARTERS.

1858	1,170	43·5	87	3·11	31	1857	964	47·4	92	5·56	23
1860	1,107	42·8	89	4·59	35	1859	710	43·0	87	7·18	48
1862	1,300	45·6	89	7·04	40	1861	1,054	46·4	88	7·23	35
1863	1,364	47·3	86	4·48	34	1864	1,292	43·6	82	4·13	29
1867	1,759	43·1	87	4·52	37	1865	1,293	46·1	88	8·92	46
1868	1,934	45·8	87	8·61	48	1866	1,418	46·5	87	5·36	41
Mean -	1,439	44·7	88	5·39	37	Mean -	1,121	45·5	87	6·39	37

minimum of cases. The distribution of 100 cases through the year may be thus represented month by month:—

In January	2·4	Winter quarter	7·9 cases.
„ February	2·7		
„ March	2·8		
„ April	3·0	Spring quarter	14·3 „
„ May	3·8		
„ June	7·5		
„ July	21·1	Summer quarter	63·4 „
„ August	27·5		
„ September	14·8		
„ October	7·5	Autumn quarter	14·4 „
„ November	4·1		
„ December	2·8		
	100·0		100·0

The spring and autumn then stand on about the same level as to the prevalence of diarrhœal affections, the winter quarter presenting only about half as many cases as either of them. The smallest number of cases was met with on the whole in the first week of the year, and, on the average of the 12 years, the coldest week of all the year. With almost complete regularity the cases increased in number week by week, until from a weekly average of 6·6 cases a weekly average of 91·8 cases was reached in the 30th week of the year, the last week in July. And then, following the line of average diarrhœa, a lessening in the number of cases occurred during two weeks, after which, in the 33rd week, the third week in August, a further rise took place, and the maximum of the year was attained. The regular diminution of diarrhœa succeeded. Now this order of occurrences gives to the summit of the average diarrhœal wave in Diagram 25 a remarkable shape, resembling the vertical section of the crater of a volcano, of which one margin is higher than the opposite. It is a fair representation of an occurrence which the annual diagrams show to have been very common in the course of summer diarrhœa, for the diarrhœal wave-line of most years exhibits more or less of this peculiar form of summit. The number of weeks intervening between the two elevated points is not always the same, nor is the relative height of these points always the same; but there is nearly always some indication more or less marked of a maximum, or apparent maximum, being attained, then of a lessening of diarrhœa, and then of a second real or apparent maximum of cases. It is well seen in the diagrams for 1857, 1858, 1861, 1863, 1864, 1865, and 1867.

I must here draw attention to the regularity with which the line of general sickness follows that of diarrhœa in the 25th diagram, from the 24th to the 37th week.

The line of diarrhœa, however, does not exactly follow that of mean temperature. The lowest part of the line indeed corresponds with the lowest weekly temperature of the year, and it rises as the mean temperature on the whole rises, and as the atmospheric humidity on the whole lessens, but very slowly and gradually. Nothing like an abrupt rise happens until the line of mean temperature marks an elevation of atmospheric warmth to 60° and upwards, in the 25th week. In like manner, during the decline of diarrhœa, the weekly diminution of this kind of sickness ceases to be rapid and becomes smaller, and the diminution more gradual in the 38th week, on the falling of the mean temperature

materially below 60°. In the interval between these periods the rise on the one side and the fall on the other is observed to be considerable week by week. And now I must direct attention to what I may term the two apexes of the cone formed by the diarrhœal line, or to what may be termed the two maximums of diarrhœa. It is to be observed that the first does not correspond with the week of highest mean temperature of the year, but points to a period two weeks later. Following now the line of mean temperature, it appears that on the whole (although it remains high) some reduction occurs in the temperature of the three or four weeks succeeding that of highest temperature, and that then a second rise to a less extent takes place prior to the final fall of the mean temperature of the year to 60° and under. This fact offers some explanation of the peculiar shape of the top of the diarrhœal wave, the second apex corresponding with the week following that of the second rise of temperature. The lesson these facts seem to teach us is this, that a high temperature does not produce diarrhœa by an immediate action upon the system, but by some more gradual process, one probably not confined to the people under its influence, but extended to their surroundings also—the soil, the water, and perhaps also the food. The diagrams for individual years may be appealed to to illustrate the same truths as the diagrammatic summary teaches. It is to be further observed that the top of the diarrhœal wave corresponds also pretty nearly with the period of greatest atmospheric dryness, although not with that of least average summer rainfall.

Table III. exhibits the relation between diarrhœa and the more important meteorological conditions present in seasons of greater or less prevalence of this class of affections. I omit the year 1866 as altogether exceptional—I shall refer to it again—and shall confine myself to the period from June to October, as embracing that which is alone important for our purpose. (See Table III., pp. 52, 53.)

The severity with which the diarrhœal season sets in in the month of June depends clearly upon the heat and dryness of the atmosphere; similar conditions governing also the prevalence of diarrhœal affections throughout the summer quarter. It is remarkable that as diarrhœa approaches the period of its quiescence in October, the months in which it prevailed most were those in which this season of the year was most strongly characterized on the whole by atmospheric humidity and rainfall.

The hot and dry year 1868 illustrates well the meteorological conditions favourable to the prevalence of diarrhœa. Cases of diarrhœa were unusually numerous from the very beginning of the spring quarter, and in the course of the summer it attained a degree of prevalence (1,309 cases) only comparable with that of the summers of 1857 and 1859, and approaching nearest of all to that of the cholera season of 1866.

The exceptional cholera year 1866 deserves particular notice, chiefly because the summer diarrhœa, the recorded cases of which amounted in the three months July, August, and September to 1,879, did not correspond to the meteorological conditions existent during its prevalence. Neither did the summit of the diarrhœal wave, as will be seen on looking at Diagram 19, correspond with that of the wave of epidemic cholera as it presented itself in this district. The mean temperature of the 13 weeks of summer was positively low, viz., 58·7°; that of the four weeks of July being 61·5°, of the four weeks of August 58·9°, and of the five weeks of September 56·9°. The humidity of the atmosphere also was great for the season, and the rainfall considerable. It was therefore impossible to fail in recognizing in this season the operation of a cause other than the ordinary meteorological causes of summer diarrhœa,

TABLE III.

MONTH of JUNE.

Seasons of greater Prevalence of Diarrhœa.						Seasons of less Prevalence of Diarrhœa.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1857 -	106	61·3	74	2·28	12	1860 -	60	54·1	83	6·25	25
1858 -	136	64·1	67	1·24	5	1861 -	110	58·8	80	1·92	16
1859 -	100	61·4	78	2·67	11	1862 -	74	56·5	80	2·02	19
1865 -	202	60·0	70	2·52	6	1863 -	98	57·4	76	3·96	15
1868 -	246	61·5	70	1·85	8	1864 -	104	56·7	73	1·31	11
						1867 -	102	60·0	76	2·47	11
Mean -	158	61·6	72	2·11	8	Mean -	91	57·2	78	2·98	16

MONTHS of JULY, AUGUST, and SEPTEMBER.

1857 -	932	63·3	77	5·73	30	1858 -	458	61·0	74	5·39	29
1859 -	946	62·8	73	7·10	33	1860 -	298	56·3	85	9·12	52
1861 -	888	60·4	78	4·20	43	1862 -	423	60·2	81	5·75	33
1863 -	889	59·1	74	5·18	27	1864 -	751	59·4	71	4·37	24
1867 -	844	59·7	78	11·40	35	1865 -	699	62·5	75	6·41	29
1868 -	1,309	64·1	70	4·40	23						
Mean -	968	61·6	75	6·33	31	Mean -	525	59·9	77	6·20	33

TABLE III.—*continued.*

MONTH of OCTOBER.

Seasons of greater Prevalence of Diarrhœa.						Seasons of less Prevalence of Diarrhœa.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1857 -	75	52·2	92	3·93	9	1860 -	70	50·2	87	1·05	10
1858 -	58	50·8	85	1·16	9	1861 -	77	56·5	89	0·95	11
1859 -	53	51·0	88	2·67	16	1863 -	81	52·9	86	1·54	14
1862 -	131	53·9	88	4·17	15	1864 -	71	50·9	77	1·03	5
1865 -	145	51·3	87	5·18	16	1867 -	86	49·1	87	1·51	16
						1868 -	69	49·4	87	2·29	14
Mean -	92	51·9	88	3·42	13	Mean -	75	51·5	85	1·39	11

producing the enormous amount of diarrhœa observed;—for the cases recorded upon the books, numerous as they were, did not represent anything like all that were admitted under treatment. A consideration of the temperature of the season week by week will put this in a still clearer light. In the fourth week of June the mean temperature was 58·1°, and in the fifth week it suddenly rose to 66·3°; in the week following it fell 10 degrees, to rise in the second week of July 12 degrees, to 68·2°, the highest weekly mean of the year. For four or five weeks after this it progressively fell to 58·0°. The month of June was not remarkable for diarrhœa, and gave no promise, had not cholera been anticipated, of a heavy diarrhœal epidemic. In the fifth week of June only 28 cases were recorded; in the first week of July there were 55 cases, and they increased week by week thus, 43, 99, 115, 165, 272, 313, the last number being attained in the third week of August, that is, five weeks after the maximum temperature of the year had been reached, the steady increase of cases having gone on concurrently with a steady decline of mean temperature below 60°. Our maximum of weekly cases of diarrhœa was attained on the second week after the most fatal week of cholera in London, which was also the week on which the largest number of cases of the disease was observed in Islington. Diarrhœa then increased as cholera declined.

Measles.

The number of cases of measles recorded during the 12 years was 5,501. It is thus made up:—

In 1857	- -	221	cases, or	17·2	per 1,000	of all cases.
„ 1858	- -	416	„	30·0	„	„
„ 1859	- -	328	„	21·7	„	„
„ 1860	- -	531	„	24·3	„	„
„ 1861	- -	280	„	12·0	„	„
„ 1862	- -	653	„	27·2	„	„
„ 1863	- -	322	„	12·0	„	„
„ 1864	- -	713	„	29·7	„	„
„ 1865	- -	200	„	8·5	„	„
„ 1866	- -	813	„	29·6	„	„
„ 1867	- -	328	„	11·9	„	„
„ 1868	- -	696	„	21·2	„	„

What strikes a person first in looking at this list is, that, in the limited district to which these figures relate, measles was epidemic regularly every second year, the only exception being that 1859 did not exhibit the full subsidence of the disease which this observation would have led one to anticipate. I do not gather from the death register that the years of greater prevalence of measles here were years of greater prevalence throughout the kingdom. It would seem as if an epidemic of measles so far exhausted the susceptibility of the population here that it did not recover itself for two years. There was nothing very decidedly in common in the meteorological conditions either of the epidemic years or of the years of less prevalence of the disease. Contrast for example the cold wet year 1860 and the excessively hot and dry year 1868. It would be interesting to know whether in other limited communities a similar observation has been made. It is remarkable also that the percentage of all cases of sickness was nearly the same number in four out of the six epidemic years, viz., 1858, 1862, 1864, and 1866. All that can be said is that on the whole, putting out 1868, the years of greater prevalence of measles were rather cooler years than those of less prevalence.

Diagram 26 exhibits the line of measles in accordance with our 12 years' experience of its distribution through the several seasons of the year. It forms two waves in the year, the one culminating in the latter part of spring, the other at the end of autumn. Of these the earlier is the more considerable wave. Assuming the yearly occurrence of 100 cases, the normal distribution of measles may be represented as follows:—

In January	7·1	Winter quarter	19·3 cases.
„ February	6·0		
„ March	6·2		
„ April	6·5	Spring quarter	30·4 „
„ May	11·3		
„ June	12·6		
„ July	10·4	Summer quarter	25·8 „
„ August	7·5		
„ September	7·9		
„ October	6·8	Autumn quarter	24·5 „
„ November	8·3		
„ December	9·4		
	100·0		100·0 „

The smallest number of cases occurred in the month of February, the largest number in June. The spring wave of the epidemic rises with some suddenness in May, but subsides more gradually to October. Altogether the spring quarter was that in which measles prevailed most; it was less prevalent in summer and autumn, and least so in the winter quarter.

Referring to the diagrams, we find that out of the six epidemic years, 1858, 1860, 1862, 1864, 1866, and 1868, there were four in which the largest number of cases occurred in the spring quarter, and only two, 1862 and 1868, in which the largest number occurred in the autumn quarter; still in 1862 the largest monthly number of cases occurred in May and June, and the next largest number in December. In 1868 the largest number of cases occurred in December.

In the non-epidemic years, 1857, 1859, 1861, 1863, 1865, 1867, spring was not so specially favoured. In two of these years, 1859 and 1865, the largest number of cases occurred in the winter quarter. In 1859 spring and summer were little less troubled with measles, the largest monthly number of cases occurring in May and September. In 1865 the winter measles was a mere prolongation of the autumnal epidemic of 1864 into January and February. The epidemic of 1866 began in December of 1865, the disease having been in abeyance from March to that month. In two of these years, 1857 and 1867, the greatest number of cases of measles occurred in the autumn. When this happened the disease abated in the succeeding winter. In only one of these years, 1863, did the largest number of cases occur in the spring, and in only one, 1861, did the largest number occur in the summer season.

In five out of the six epidemic years, not only was there a large number of cases forming a wave of measles culminating in the spring and early part of summer, but there was a considerable autumnal wave also. The exceptional year was the cold wet year 1860, when the autumnal wave did not occur at all. Only in two out of these five years was the autumnal wave greater than the spring wave, namely in 1862 and 1868. In 1862 it was very slightly greater, the greatest monthly number of cases occurring in June and July. In 1868 the disease steadily in-

creased quarter by quarter as the year progressed, the summer cases exceeding the spring slightly, and the winter greatly exceeding either. The largest number of cases happened in November and December.

In four out of six of the non-epidemic years there was an autumnal wave greater than the spring wave, viz., in 1857, 1861 (slightly), 1865, and 1867 (considerably).

Although it must be concluded that on the whole measles is more abundant in the spring quarter, yet the occurrence of an autumnal wave must be regarded as a more constant event.

There were four years out of the 12, viz., 1861, 1866, 1867, and 1868, in which measles was more abundant in the summer than in the spring quarter. In 1861 the largest number of cases occurred in August; in 1866 about an equal proportion of cases happened in June, July, August, and September; in 1867 there were more cases in July and August than in June; and in 1868 the disease, which prevailed considerably in May, declined during June, July, and August, to increase in September up to the end of the year.

In searching for the meteorological conditions which occasion the waves of measles, which promote its increase or its decline, we may first of all consider the habitual meteorological conditions of those seasons which our 12 years' experience teach us are favourable to the spread of the disease, or the reverse.

And here we must recollect that the law by which contagious diseases spread in a population is, that when once started under favourable conditions of weather and season, another element of rapid extension comes into play, namely, the growing increase in the number of foci of contagion; so that so long as the conditions of weather and season are not absolutely unfavourable to the life and development of the morbific germs, the disease increases in extent, and does not lessen until either the susceptibility of the population is exhausted, or conditions of season come about absolutely unfavourable to the spread of the malady. Moreover in estimating the conditions of weather favourable to measles, or the reverse, we must bear in mind that this disease has an incubation of about 14 days, and make an allowance accordingly. I must give this as an instruction in the reading of the diagrams so far as measles is concerned. In the decline of an epidemic we must similarly bear in mind the progressive diminution of the foci of contagion. Now referring to my records of the 12 years, I find that on the average measles began to assume its epidemic character in the 18th week of the year, that is, in the first week of May. The average weekly meteorological conditions and average weekly number of cases of measles for each week about this time were as follows:—

—	Average of new Cases Two Weeks later.	Mean Temperature.	Mean daily Range of Temperature.	Mean Humidity.	Mean Rainfall.	Rainy Days in 12 Years.
		°	°		Inches.	
12th week	5·2	40·9	15·0	81	0·41	33
13th "	7·2	45·4	15·8	81	0·38	45
14th "	6·0	46·6	17·4	82	0·38	34
15th "	8·8	46·6	17·4	81	0·44	40
16th "	11·0	48·2	20·3	75	0·14	19
17th "	11·5	49·1	18·9	79	0·50	32
18th "	14·1	49·2	19·2	74	0·22	23

From which we may gather that the conditions most favourable to the outbreak of the spring epidemic of measles are, the rise of the mean tem-

perature to 48° or upwards, with an increase of daily range to 20° and upwards, combined with a lowering of the atmospheric humidity to 75° and under, the rainfall and the number of wet days being at the same time much below the average of the whole season. It is worthy of notice that the meteorological averages of the 17th week exhibited a return towards those of the 15th, and that with this the average of cases of measles was nearly stationary. Again, that on the average temperature rising in the 18th week above that of the 16th, with a reduction in the humidity and rain, measles rose again above the average of the 16th week.

Again, the average number of cases of measles began to fall permanently in the 28th week, that is, in the second week of July. The average of cases and meteorological conditions about this time were as follows :—

—	Average of new Cases Two Weeks later.	Mean Temperature.	Mean daily Range of Temperature.	Mean Humidity.	Mean Rainfall.	Rainy Days in 12 Years.
		°	°		Inches.	
22d week	14·8	57·8	21·1	76	0·82	33
23d „	13·3	58·5	20·5	78	0·63	32
24th „	12·3	58·8	21·8	74	0·35	26
25th „	13·2	60·2	22·0	75	0·47	32
26th „	12·1	60·4	20·7	74	0·48	32
27th „	10·1	59·9	21·5	74	0·40	29
28th „	8·0	63·6	23·7	73	0·23	17
29th „	9·0	63·5	20·2	73	0·59	30

From which it appears that the condition and the only condition which this table indicates, as concerned in the arrest of the spread of measles, is the rise of the temperature of the atmosphere above a mean of 60°.

And now for the autumnal epidemic. The first outbreak of this took place on the average of the 12 years in the 47th week of the year, that is, in the last week of November. The averages about this time are as follows :—

—	Average of new Cases Two Weeks later.	Mean Temperature.	Mean Daily Range.	Mean Humidity.	Mean Rainfall.	Rainy Days in 12 Years.
		°	°		Inches.	
42nd week	7·2	51·2	14·3	88	0·87	46
43rd „	8·6	48·8	14·1	89	0·54	35
44th „	8·2	46·7	14·8	88	0·47	41
45th „	11·0	43·0	13·1	87	0·30	24
46th „	10·7	41·6	12·7	88	0·49	30
47th „	12·3	41·2	12·4	88	0·44	34
48th „	8·6	42·2	10·3	88	0·44	40
49th „	10·1	42·9	10·9	90	0·46	42
50th „	7·4	41·5	9·2	88	0·35	36
51st „	9·0	40·8	10·4	86	0·28	29
52nd „	7·0	39·6	9·7	87	0·31	31
1st „	8·1	35·2	9·9	85	0·39	40
2nd „	5·5	37·4	10·3	87	0·63	41

This seems to show that the arrival of the temperature below 49° and especially to about 43°, with a diminution of range to about 13 degrees, and again (as in the spring) a small rainfall for the season, are the conditions which favour the outbreak of the autumnal epidemic.

The circumstances promotive of the decline of the autumnal epidemic are less obvious; all that appears clearly is, that it shows a manifest disposition to decline on the fall of the mean temperature below 42°.

Putting the characters of the two epidemic seasons together, I think we may conclude that—1. The conditions promotive of an outbreak of measles in any year are a temperature between 43° and 48°.—2. That a low atmospheric humidity and small rainfall assist materially in promoting an outbreak. Probably the higher humidity of the autumn than of the spring is one reason why ordinarily the autumnal epidemic is less extensive than the spring epidemic.—3. That a rise of mean temperature above 60° and a fall below 42° tend distinctly to arrest an epidemic.

Table IV. (pp. 59, 60) exhibits the leading meteorological condition of each quarter of the several years, dividing the quarters into those in which measles prevailed more or less. It seems to show—

1. That in the *winter* season a comparatively warm and dry atmosphere with excess of rainfall are conditions which favour the extension of measles among a population more than the opposite conditions.

2. That in the *spring* a comparatively cool season with atmospheric dryness and excess of rainfall promote the spread of the disease.

3. That in the *summer* measles spreads more when the atmosphere is comparatively cool and moist, with excessive and frequent rains.

4. That in the *autumn* a comparatively warm dry atmosphere with small rainfall is most favourable to the operation of the morbific cause.

These inferences, although at the first blush contradictory to those just enunciated, need not be regarded as actually so. The former may relate to the conditions favourable to the life and development of the germs, the latter to those which predispose a population, just as bad hygienic conditions generally would do, to suffer from the malady.

There is only one other point I need draw attention to in relation to the line of measles in the diagrams, and this is, that making the necessary fortnight's allowance (or thereabouts) for incubation, measles appears to have increased commonly after any great alteration of mean temperature, whether by way of increase or diminution. That is to say, one is led to expect from the experience of the 12 years, especially when an epidemic is due, that it will break out about a fortnight after the occurrence of a serious rise in the mean temperature of the year, and that in its progress an increase of cases may be anticipated in the second week following any considerable rise or fall of temperature. In the autumn, as the temperature of 48° is approached, the outbreak of the epidemic may be anticipated when a serious fall of mean temperature occurs.

There was among the 12 years one only in which measles pretty steadily increased quarter by quarter through the year, the autumnal epidemic being more serious than the spring epidemic. This was the year 1868; hence it is instructive. The spring epidemic broke out very suddenly in the 17th week of the year, that is, in the last week of April. There was some abatement in the month of August, but it burst out afresh and with severity in the middle of September, and was very severe as the year closed. Hence it will be desirable to exhibit in a table the corresponding meteorological conditions.

APPENDIX.

No. 2.

On the Results of an Analysis of Records of Sickness, &c., by Dr. Ballard.

TABLE IV.

WINTER QUARTERS.

Of greater Prevalence of Measles.						Of less Prevalence of Measles.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1859 -	98	43·3	83	2·55	33	1857 -	59	36·3	85	3·79	35
1864 -	190	38·2	82	4·27	37	1858 -	64	37·9	81	3·41	20
1865 -	101	36·6	82	5·94	45	1860 -	75	38·9	82	3·80	52
1866 -	188	41·2	83	9·55	51	1861 -	63	39·7	89	4·96	40
						1862 -	35	40·6	86	5·73	43
						1863 -	69	42·5	83	4·08	35
						1867 -	53	38·5	83	6·29	51
						1868 -	55	41·1	82	6·52	46
Mean -	144	39·8	82	5·56	41	Mean -	59	39·4	84	4·83	40

SPRING QUARTERS.

1858 -	149	54·7	72	5·07	30	1857 -	51	54·3	76	4·06	31
1860 -	260	50·5	80	10·36	49	1859 -	91	54·2	77	6·40	29
1862 -	207	53·1	82	7·61	46	1861 -	56	51·6	81	4·73	30
1864 -	322	53·5	73	3·48	22	1863 -	100	52·6	77	5·99	34
1866 -	206	52·9	75	8·00	35	1865 -	26	56·3	72	7·24	24
1868 -	177	55·1	74	4·22	21	1867 -	53	54·3	77	6·27	39
Mean -	220	53·3	76	6·45	33	Mean -	62	53·9	77	5·78	31

TABLE IV.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Measles.						Of less Prevalence of Measles.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1858 -	89	61·0	74	5·39	29	1857 -	36	63·3	77	5·73	30
1859 -	91	62·8	73	7·10	33	1861 -	95	60·4	78	4·20	43
1860 -	130	56·3	85	9·12	52	1863 -	77	59·1	74	5·18	27
1862 -	196	60·2	81	5·75	33	1864 -	82	59·4	71	4·37	24
1866	283	58·7	80	7·93	45	1865 -	32	62·5	75	6·41	29
1868 -	197	64·1	70	4·40	23	1867 -	89	59·7	78	11·40	35
Mean -	164	60·5	77	6·61	35	Mean -	68	60·7	76	6·21	31

AUTUMN QUARTERS.

1858 -	114	43·5	87	3·11	31	1857 -	75	47·4	92	5·56	23
1862 -	215	45·6	89	7·04	40	1859 -	48	43·0	87	7·18	48
1864 -	119	43·6	82	4·13	29	1860 -	66	42·8	89	4·59	35
1866 -	136	46·5	87	5·36	41	1861 -	66	46·4	88	7·23	35
1867 -	133	43·1	87	4·52	37	1863 -	76	47·3	86	4·48	34
1868 -	267	45·8	87	8·61	48	1865 -	41	46·1	88	8·92	46
Mean -	164	44·7	87	5·46	37	Mean -	62	45·5	88	6·32	36

—	No. of new Cases Two Weeks later.	Mean Temperature.	Mean Daily Range.	Mean Humidity.	Rainfall.	Rainy Days.
1868.		°	°		Inches.	
12th week	0	44·0	17·3	84	0·07	3
13th " -	5	42·7	15·0	77	0·51	3
14th " -	4	45·2	23·3	78	0·00	0
15th " -	20	45·7	20·5	77	0·39	2
16th " -	20	45·7	18·9	82	0·10	1
17th " -	27	50·2	14·8	81	1·47	6
18th " -	17	53·0	20·9	73	0·12	1
19th " -	20	53·3	26·7	73	0·03	1
20th " -	10	57·5	24·9	77	0·00	0
21st " -	8	59·4	24·0	73	0·26	2
22nd " -	22	59·2	23·0	77	*1·38*	3
23rd " -	14	58·6	22·9	76	0·14	2
24th " -	10	60·3	25·4	63	0·00	0
25th " -	13	65·4	27·9	69	0·04	1
26th " -	15	63·6	25·6	68	0·29	2
27th " -	18	61·6	23·4	68	0·01	1
28th " -	17	65·7	27·2	64	0·13	1
29th " -	10	*70·7*	*27·8*	*64*	0·70	2
30th " -	10	69·2	27·8	59	0·01	1
31st " -	14	67·6	26·5	64	0·23	2
32nd " -	18	69·8	24·7	65	0·14	1
33rd " -	17	64·3	21·4	71	0·37	3
34th " -	5	61·9	*12·2*	*87*	1·97	6
35th " -	25	58·1	*19·4*	*74*	0·06	1
36th " -	21	65·3	26·9	77	0·00	0
37th " -	14	64·0	25·5	70	0·00	0
38th " -	20	57·1	17·0	71	0.27	1
39th " -	23	58·4	18·2	80	0·51	4
40th " -	14	53·7	*12·3*	*85*	1·17	5
41st " -	13	51·8	18·5	87	0·60	3
42nd " -	15	49·7	20·1	88	0·03	2
43rd " -	22	*42·6*	16·4	90	0·49	4
44th " -	27	46·8	13·7	87	1·06	3
45th " -	23	43·9	13·9	83	0·18	2
46th " -	13	40·7	10·5	85	0·06	3
47th " -	18	39·8	11·4	84	0.04	2
48th " -	23	42·5	9·3	92	0·88	5
49th " -	32	45·6	7·7	91	0·31	4
50th " -	24	47·6	9·7	87	1·30	4

In studying this table it must be kept in mind that 1868 was a year in which an epidemic of measles was due, and had it not been for the remarkable temperature and drought of the spring and early summer, the epidemic would have prevailed, in all probability, chiefly in this season. As it was, these conditions seem to have checked its progress, and deferred the severity of the outbreak until the temperature fell to a point at which the morbific germs could be in circumstances to operate effectually upon the population whose susceptibility had not yet been exhausted. The outbreak commenced about a fortnight or three weeks after a period of remarkable absence of rain, the temperature having arrived midway between 43° and 48°, the range being about 20 degrees, and the humidity of the atmosphere for a short time having fallen to about 77. I have emphasized in the table some of the occurrences in certain weeks. In the 22nd week, after long drought, a heavy rainfall (comparatively) occurred, and measles rose a fortnight after from eight cases to 22 in the week. It subsided remarkably after the 24th week, in association with a remarkable rise of temperature with very unusual dryness of the atmosphere and lack of rain, and another decided subsidence took place

in the 30th week; a fortnight after the mean temperature had attained the excessive height of 70·7° with a mean daily range of 27·8°, and a humidity of only 64, and this notwithstanding comparatively much rainfall in that week. Measles again underwent a remarkable fall in the 36th week from 17 cases to 5, the 34th week being distinguished from those before and succeeding it by a very high atmospheric humidity and an unusually small mean daily range for the season, and this again notwithstanding the heavy and continued rainfall. In the next week measles increased again on the reduction of the mean temperature below 60°, with greater range and a humidity of 71. In the 42nd week another remarkable reduction of measles occurred, following a curious and sudden reduction of range and increase of humidity, and again uninfluenced by the heavy and continued rainfall. The latter seems only to have operated in promoting the spread of measles in this year when not associated with a high atmospheric humidity. Measles again underwent a great increase, the commencement of the autumnal epidemic in the 45th week. In the 42nd the mean temperature first fell considerably below 50°. A temperature about or below 40° in the 46th or 47th weeks evidently checked its progress, but it recovered itself when in the 48th week the mean temperature again rose to or above 42·5°.

Scarlatina.

The number of cases of scarlatina recorded during the 12 years was 3,850. It is thus made up :—

In 1857 -	- 75	cases, or	5·8	per 1,000	of all cases.
„ 1858 -	- 162	„	11·7	„	„
„ 1859 -	- 426	„	24·9	„	„
„ 1860 -	- 232	„	10·6	„	„
„ 1861 -	- 247	„	10·5	„	„
„ 1862 -	- 299	„	12·4	„	„
„ 1863 -	- 630	„	23·5	„	„
„ 1864 -	- 269	„	11·2	„	„
„ 1865 -	- 292	„	12·4	„	„
„ 1866 -	- 255	„	9·2	„	„
„ 1867 -	- 524	„	19·1	„	„
„ 1868 -	- 439	„	13·4	„	„

It is observable that three non-epidemic years intervened between the epidemic years 1859 and 1863, and three again between the epidemic years 1863 and 1867. Last year, in all respects exceptional, was also marked by an epidemic of scarlatina, but of less extent than that in 1867. On the whole these epidemic years were years of comparatively high mean temperature and atmospheric dryness. Putting aside the epidemic years, the prevalence of scarlatina in the non-epidemic years did not differ very materially. The proportion of scarlatina to all cases of sickness differed very little in 1859 and 1863. In 1867, the fourth year from the last epidemic, the outbreak of scarlatina was on the whole less severe, perhaps in association with the comparatively low mean temperature of the year. 1868 should, in accordance with previous experience, have been a non-epidemic year; and in point of fact, although the cases were very numerous absolutely, the proportion borne to all cases of sickness was not much higher than that in 1862 and 1865. Probably the comparatively high absolute number was due to similar causes which occasioned the great general sickness among the poor last year, combined with the excessive heat and dryness of the first three quarters.

Diagram 26 exhibits the line of distribution of scarlatina through the

several seasons of the year, in accordance with our 12 years' experience. Scarlatina forms but one grand wave in the year.

Assuming the yearly occurrence of 100 cases, the following indicates the proportion of cases which occurred in the several seasons of the year :—

In January	6·5	Winter quarter, 17·7 cases.
„ February	6·8	
„ March	4·4	
„ April	5·7	Spring quarter, 17·3 „
„ May	5·6	
„ June	6·0	
„ July	9·1	Summer quarter, 29·9 „
„ August	8·6	
„ September	12·2	
„ October	14·5	Autumn quarter, 35·1 „
„ November	11·4	
„ December	9·2	
	100·0	100·0

The smallest number of cases occurred in the month of March, and the prevalence of the disease has been in our experience greater as the spring and summer advanced, until the month of October, in which the disease has been observed to be more prevalent than in any other. From October it has been observed to become less prevalent, through November, December, January, and February to March. Scarlatina, then, is a disease which attaches itself with very marked preference to the latter half of the year. It is curious that it should be about equally prevalent on the whole in months of such opposite characters as July and December.

Of the four epidemic years, 1859, 1863, 1867, and 1868, there were two, 1859 and 1867, in which the largest number of cases occurred in the autumn quarter ; in the other two years, 1863 and 1868, the largest number occurred in the summer quarter.

Of the eight non-epidemic years there were four, 1857, 1858, 1864, and 1865, in which the summer quarter exhibited the largest quantity of scarlatina ; three, 1861, 1862, and 1866, in which the greatest number of cases occurred in the autumn.

It would appear as if some preparation were made, or warning given, the year previous to an epidemic of scarlatina. Thus in 1858 scarlatina suddenly burst out in the month of September, with 51 cases in five weeks (14 having been recorded in August). It then subsided as the autumn proceeded, but still there was a considerable number of cases. It fell almost into abeyance in February and March of 1859, after which it increased quarter by quarter to the end of the year. The great outburst began in September. The last week of this month, with the whole of October and November, up to the last week of that month, embraced the worst period of the most extensive epidemic of the whole 12 years. It did not completely come to an end until the end of March 1860.

Again, the grand epidemic year 1863 was preceded by a sharp autumnal outbreak in 1862. Indeed, one may go so far as to regard this epidemic as extending without break from September 1862 to the end of 1863. The 1859 epidemic came to an end in April 1860 ; and with the exception of the ordinary increase of the disease which may be expected every summer and autumn, nothing remarkable was observed until the end of the summer of 1861. In September, October, and

November a slight epidemic wave occurred, which extended, subsiding, however, through the winter of 1862. The disease almost died out in June, but gradually increased afterwards; and in September began the heavy epidemic which only terminated with the end of the next year, 1863. There was merely some little abatement of the epidemic violence at times during the winter and spring of 1863, but from July to October it exhibited its chief activity.

The epidemic which we have last experienced commenced with an outburst of the disease in the autumn of 1866. It subsided a little during the winter quarter of 1867, but then increased from April, month after month, until October, upon which month the chief violence of the epidemic was expended. A partial subsidence of the disease then commenced, continuing through January, February, and March 1868. The spring months of this year, however, saw the epidemic reviving; and it was as severe, to say the least, in the spring and summer of 1868 as in those of 1867. After September the epidemic declined, and only 99 cases were recorded in the autumn quarter of 1868, against 222 in the corresponding period of the previous year.

Unlike measles, scarlatina has so brief an incubation that it may be disregarded practically in any consideration of its meteorological associations. Following the same method of inquiry that we pursued with measles, we may study, on the following table, first of all, the conditions which, on the average of years, seem to promote the outbreak of the disease or favour its decline. We may consider the disease as usually pretty much in abeyance until about the 27th week of the year, that is, the first week in July.

—	Average of new Cases.	Mean Temperature.	Mean daily Range.	Mean Humidity.	Mean Rainfall.	Rainy Days, 12 Years.
		°	°		Inches.	
24th week	4·0	58·8	21·8	74	0·35	
25th „ -	4·0	60·2	22·0	75	0·47	
26th „ -	3·6	60·4	20·7	74	0·48	
27th „ -	*6·5*	*59·9*	*21·5*	*74*	*0·40*	
28th „ -	6·7	63·6	23·7	73	0·23	
29th „ -	7·0	63·5	20·2	73	0·59	
30th „ -	6·6	62·0	21·4	73	0·63	
31st „ -	5·4	61·1	22·4	71	0·39	
32nd „ -	6·7	62·4	21·2	76	0·65	
33rd „ -	6·5	62·2	20·0	76	0·40	
34th „ -	6·8	60·8	19·3	78	0·74	
35th „ -	7·7	59·8	19·9	76	0·38	
36th „ -	7·5	60·3	18·9	79	0·48	
37th „ -	8·2	58·7	16·3	78	0·50	
38th „ -	*10·2*	*56·7*	*16·2*	*79*	*0·40*	
39th „ -	11·5	55·5	17·1	84	0·55	
40th „ -	12·3	54·5	16·2	83	0·37	
41st „ -	*11·5*	*52·5*	15·1	87	0·50	
42nd „ -	9·9	51·2	14·3	88	0·87	
43rd „ -	9·2	48·8	14·1	89	0·54	
44th „ -	10·1	46·7	14·8	88	0·47	
45th „ -	7·3	43·0	13·1	87	0·30	
46th „ -	8·3	41·6	12·7	88	0·49	
47th „ -	8·0	41·2	12·4	88	0·44	
48th „ -	8·4	42·2	10·3	88	0·44	
49th „ -	8·8	42·9	10·9	90	0·46	
50th „ -	6·5	41·5	9·2	88	0·35	
51st „ -	5·9	40·8	10·4	86	0·28	
52nd „ -	4·4	39·6	9·7	87	0·31	

There were two periods then at which an increase of scarlatina took place. The first, a moderate increase in the first week of the summer quarter on the arrival of the yearly rise of mean temperature to or about 60°. The other, as the summer was closing, when the mean temperature had recently arrived again at about 60° and had begun to fall below it. In the instance of the first increase it is observable that some force was evidently operating antagonistic to the active propagation of the disease, in the latter increase some condition was operating favourable to its propagation. The rainfall was not very different in the two instances, but there was a decided difference in the range of temperature on and after the 27th week of the year and that on and after the 38th week. On and after the 27th week the mean daily range was 21 degrees and upwards, and the humidity was low, from 73 to 76. On and after the 38th week the mean daily range was below 16 degrees, and the humidity 79 and upwards to 83. It is observable that the decline of the disease in the mean of years began to take place as the mean temperature and range fell below 53° and 16°, and the humidity rose to 87 and upwards.

The inferences apparently deducible are, that—

1. A mean atmospheric temperature of about 60° or between 56° and 60°, is that most favourable to the outbreak of scarlatina. 2. That for its free development it is necessary that the humidity of the atmosphere shall not much exceed 86, or be much less than 74. 3. That a higher temperature than 60° does not appear to be in itself unfavourable to the spread of scarlatina. 4. That a fall of mean temperature below 53° tends to arrest an epidemic of this disease.

Table 5 exhibits for each quarter the most important meteorological conditions of the seasons in which scarlatina was more or less prevalent. (See Table V., pp. 66, 67.) From this it appears :—

1. That at *all seasons* of the year, but more decidedly in the winter and spring—seasons in which scarlatina is not commonly epidemic—its extension is favoured by a temperature above the average of the season.

2. That at all seasons *except the autumn*, a dry as well as a warm atmosphere is calculated to promote its epidemic prevalence.

3. That in the *winter*, *spring*, and *summer* the disease is less disposed to spread when a good deal of rain is associated with the comparatively low temperature and high atmospheric humidity, but in the *autumn* the table indicates that the warmer and wetter seasons were those which proved most favourable to the extension of the epidemic.

One word about the epidemic prevalence of scarlatina last year. In accordance with the experience of former epidemics, the epidemic of 1867 might have been expected to terminate in the winter of 1868 That it did not, but that it extended through the year, was probably due to two causes—the high temperature and atmospheric dryness of the winter, spring, and summer, and the operation of those general causes of sickliness among the poor which have already been referred to.

Hooping Cough.

The 4,580 cases of hooping cough recorded during the 12 years were distributed among them thus:—

In 1857 - -	218 cases,	or 17·0	per 1,000	of all cases.	
„ 1858 - -	372	„ 26·8	„	„	
„ 1859 - -	259	„ 17·1	„	„	
„ 1860 - -	264	„ 12·0	„	„	

TABLE V.

WINTER QUARTERS.

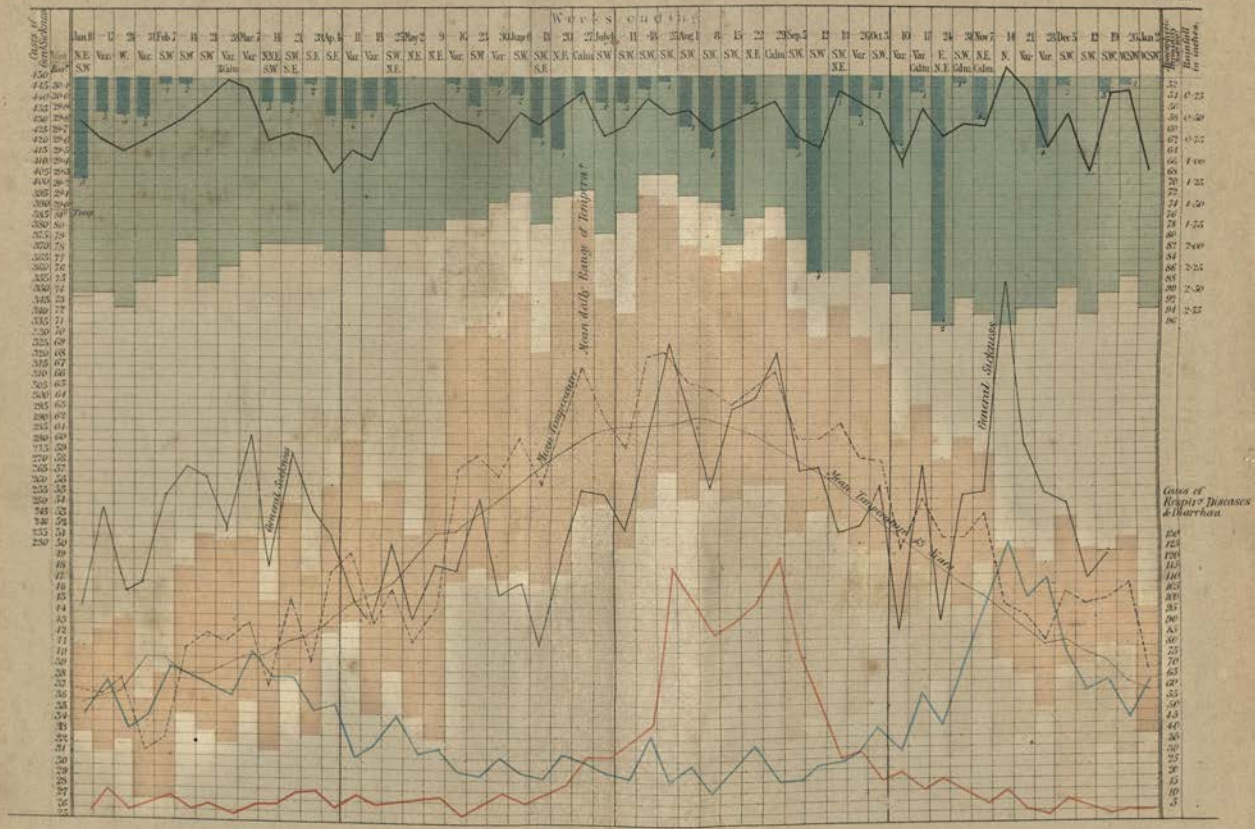
Of greater Prevalence of Scarlatina.						Of less Prevalence of Scarlatina.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1859 -	35	43·3	83	2·55	33	1857 -	10	36·3	85	3·79	35
1860 -	76	38·9	82	3·80	52	1858 -	8	37·9	81	3·41	20
1863 -	129	42·5	83	4·08	35	1861 -	19	39·7	89	4·96	40
1865 -	72	36·6	82	5·94	45	1862 -	65	40·6	86	5·73	43
1867 -	71	38·5	83	6·29	51	1864 -	50	38·2	82	4·27	37
1868 -	94	41·1	82	6·52	46	1866 -	41	41·2	83	9·55	51
Mean -	79	40·1	82	4·86	43	Mean -	32	39·0	84	5·28	37

SPRING QUARTERS.

1859 -	67	54·2	77	6·40	29	1857 -	7	54·3	76	4·06	31
1863 -	119	52·6	77	5·99	34	1858 -	14	54·7	72	5·07	30
1864 -	58	53·5	73	3·48	22	1860 -	36	50·5	80	10·36	49
1865 -	55	56·3	72	7·24	24	1861 -	28	51·6	81	4·73	30
1867 -	95	54·3	77	6·27	39	1862 -	37	53·1	82	7·61	46
1868 -	105	55·1	74	4·22	21	1866 -	50	52·9	75	8·00	35
Mean -	83	54·3	75	5·60	28	Mean -	28	52·8	78	6·63	36

1857.

No. 1.



Respiratory Diseases ——— Diarrhœa ———

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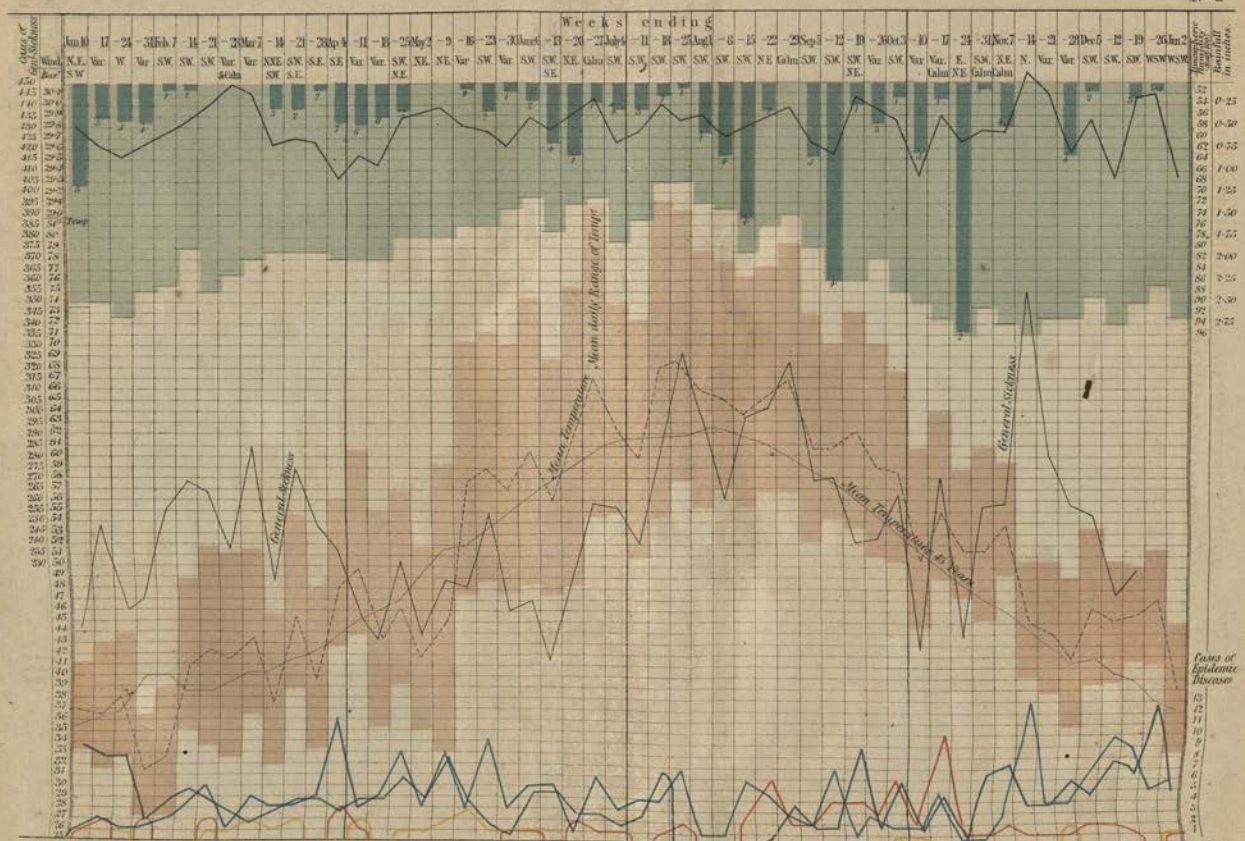
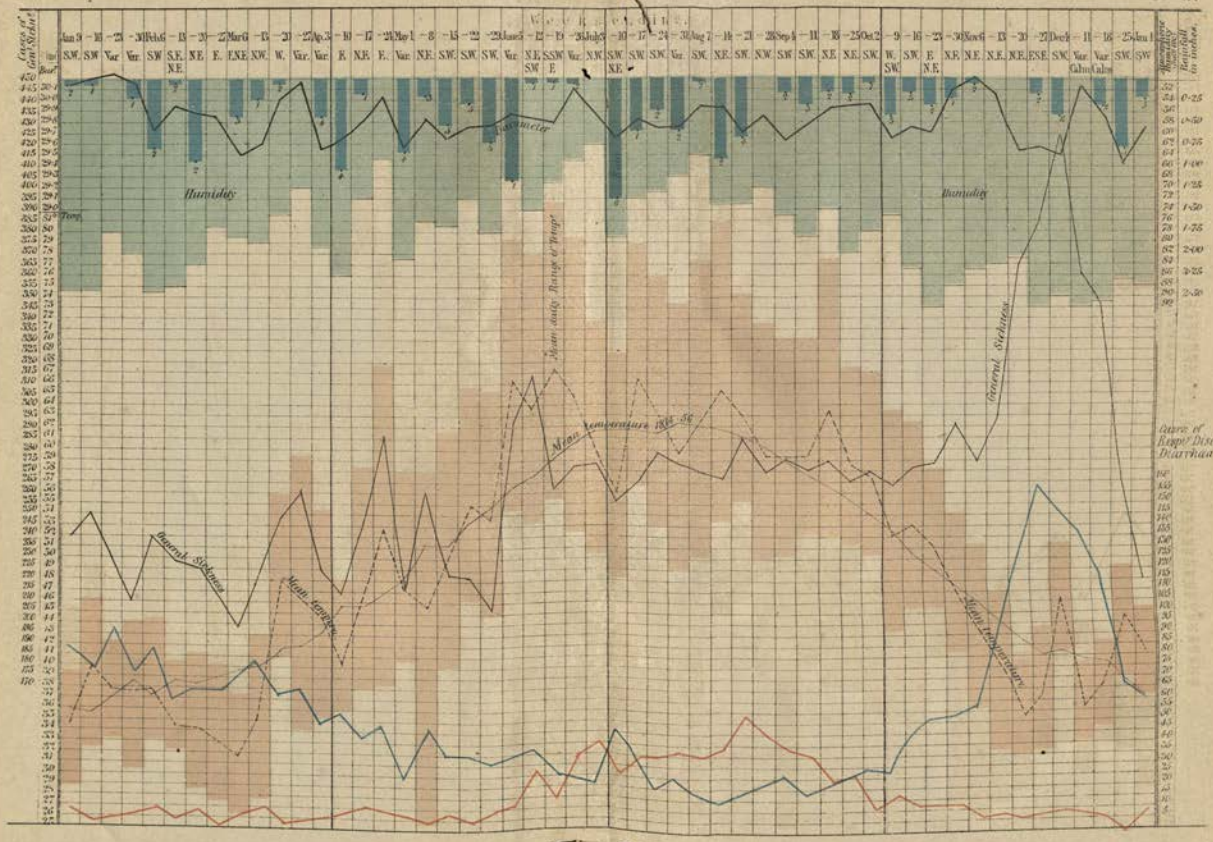
1857.

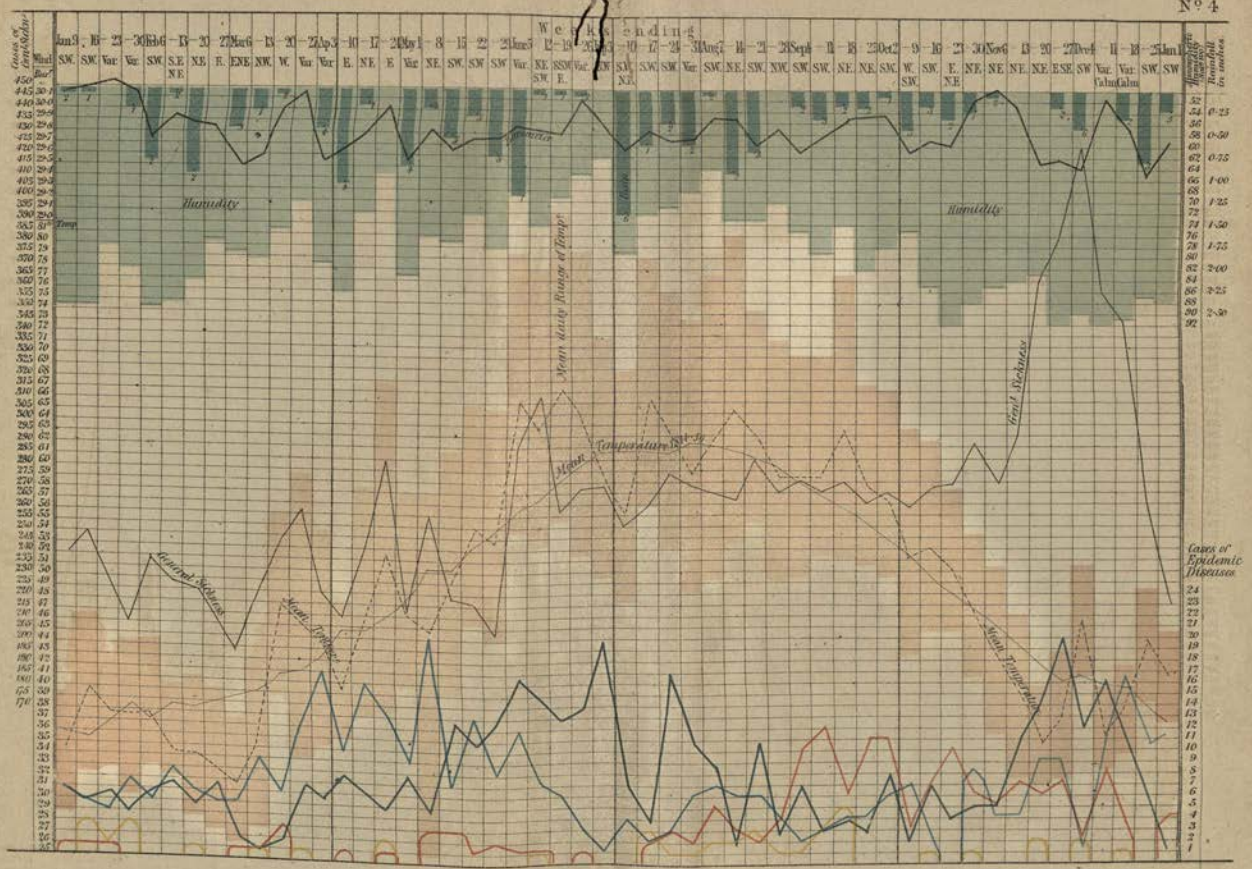
No. 2



Weeks ending
Cases of Gen. Sickness
Wind
Bar
Temp
Mean daily Range of Temp.
Mean Temperature
Mean Temperature 45 Years
General Sickness
Cases of Epidemic Diseases
Measles
Scarlatina
Small pox
Hooping Cough

No. 3.


Weekly Results
Cases of Genl Sickness
Humidity
Temp
Barometer
Mean daily Range of Temp^r
Mean temperature 1854-56
General Sickness
Mean temperature
Cases of Resp^y Diseases Diarrhœa
Rainfall in inches
Diarrhœa
Respiratory Diseases



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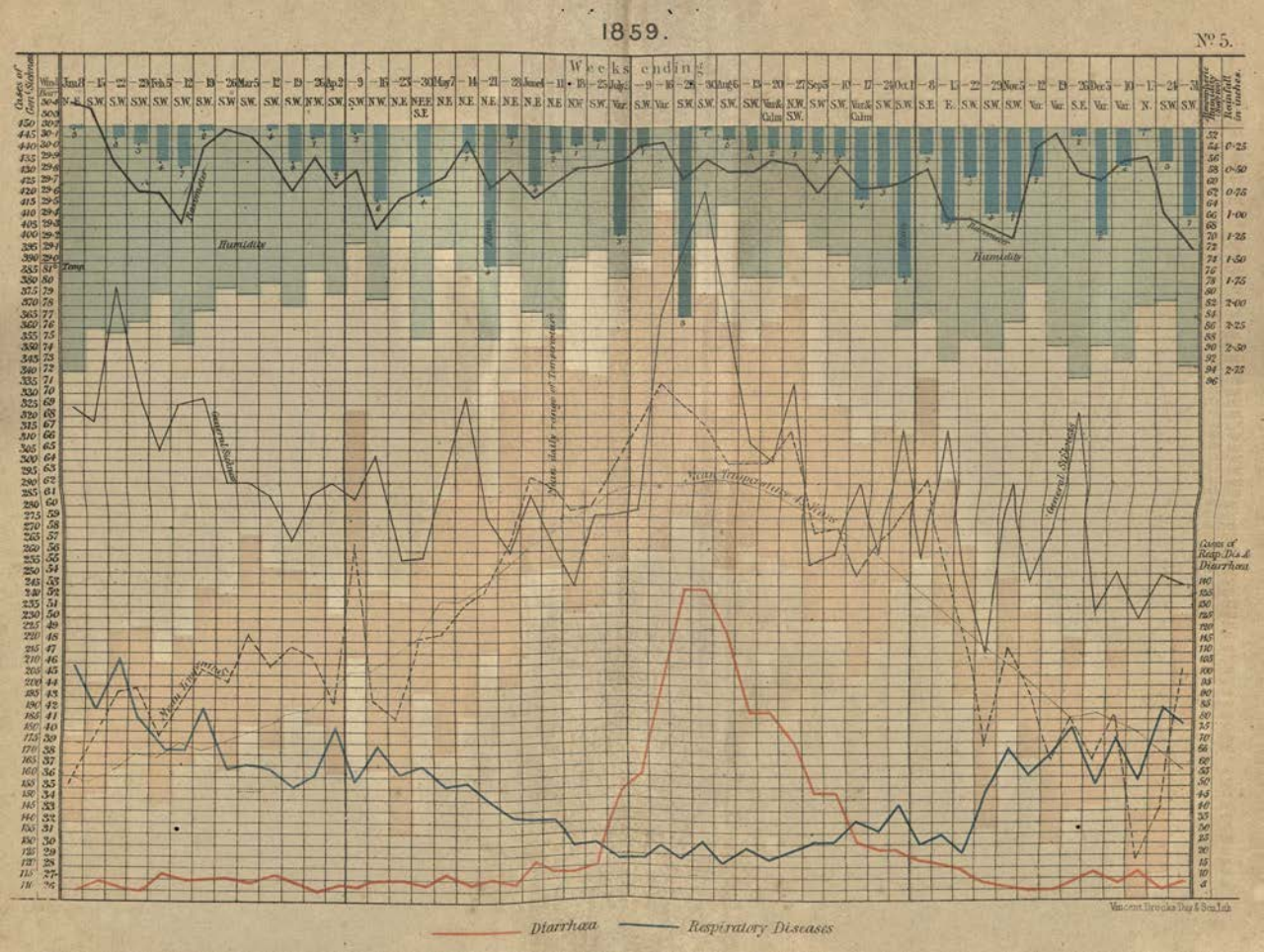
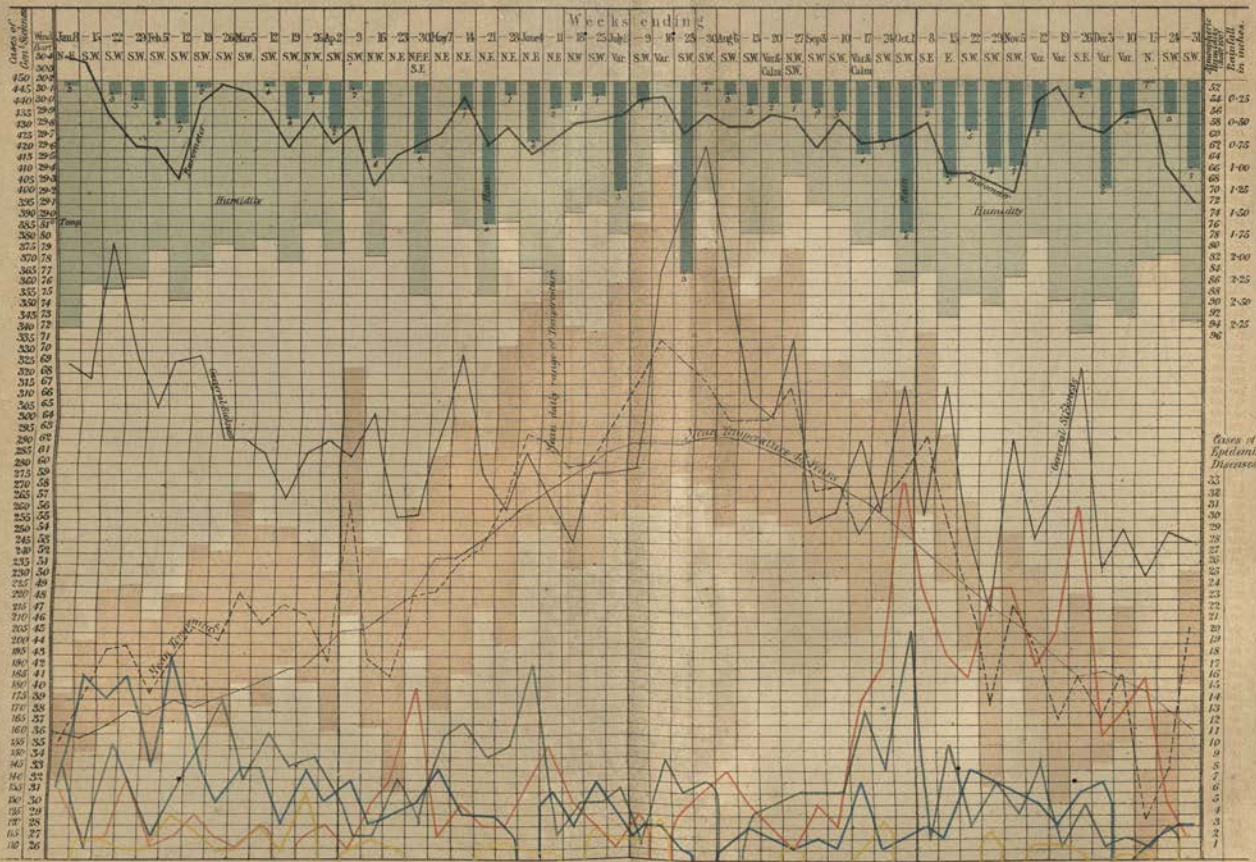

1859.
No. 5.
Weeks ending
Cases of Gen. Sickness
Cases of Resp. Dis. & Diarrhœa
Humidity
Temp.
Rain
Barometer
Mean daily range of Temperature
Mean Temperature 4 Years
General Sickness
Diarrhœa
Respiratory Diseases
Vincent Brooks Day & Son Lith.

1859.

No 6.



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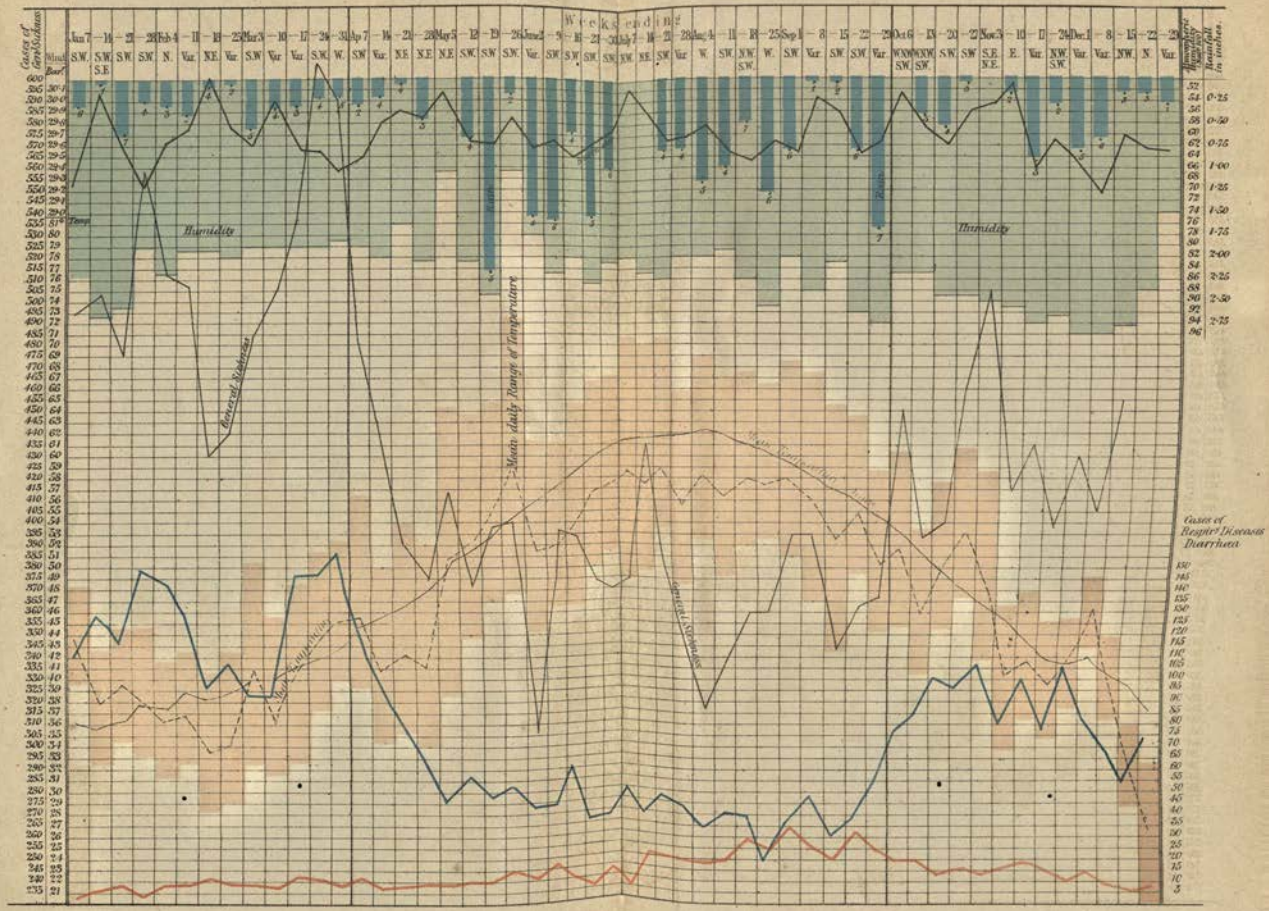
1860.



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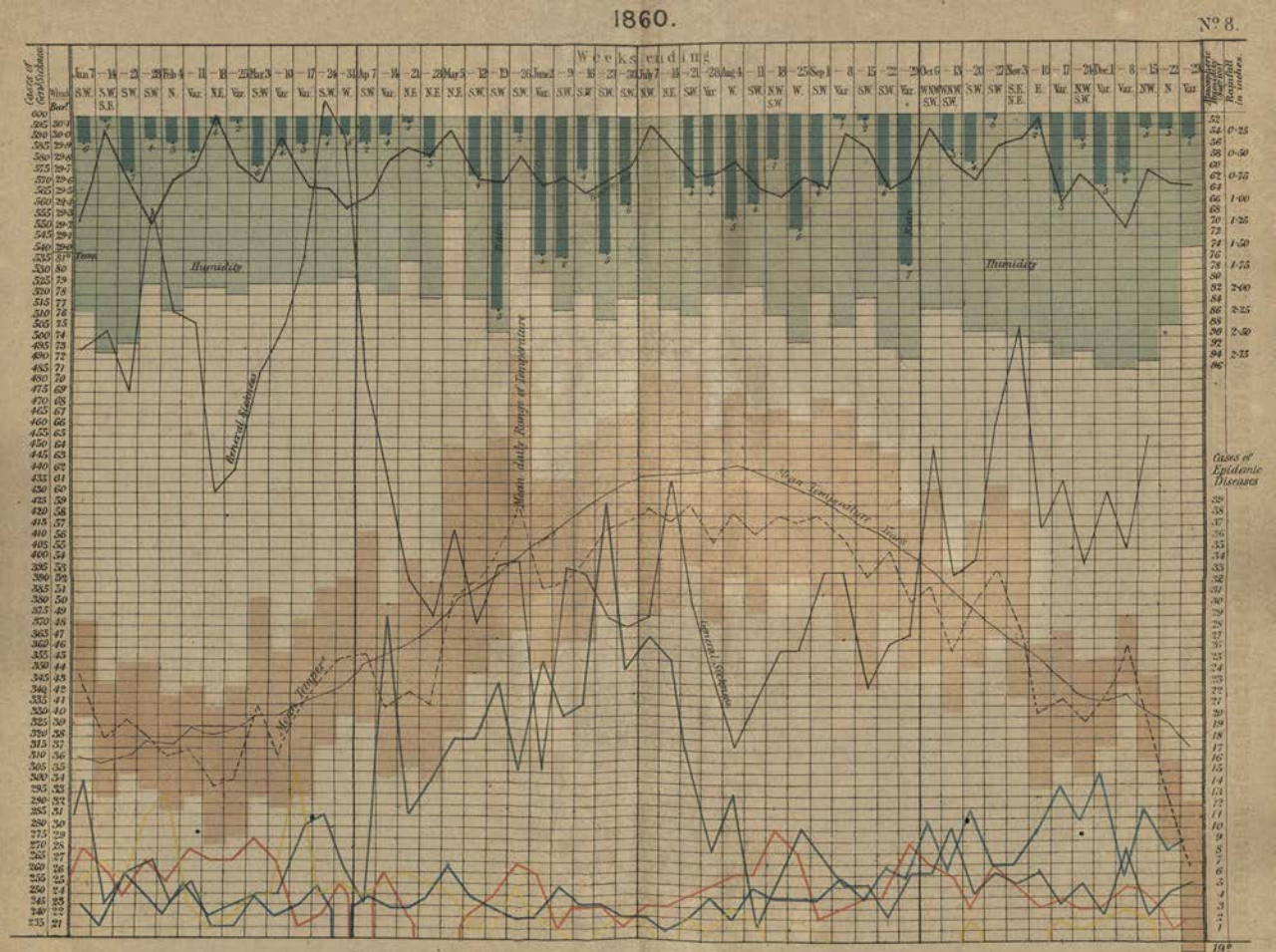
1860. Nº 8.



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1861.

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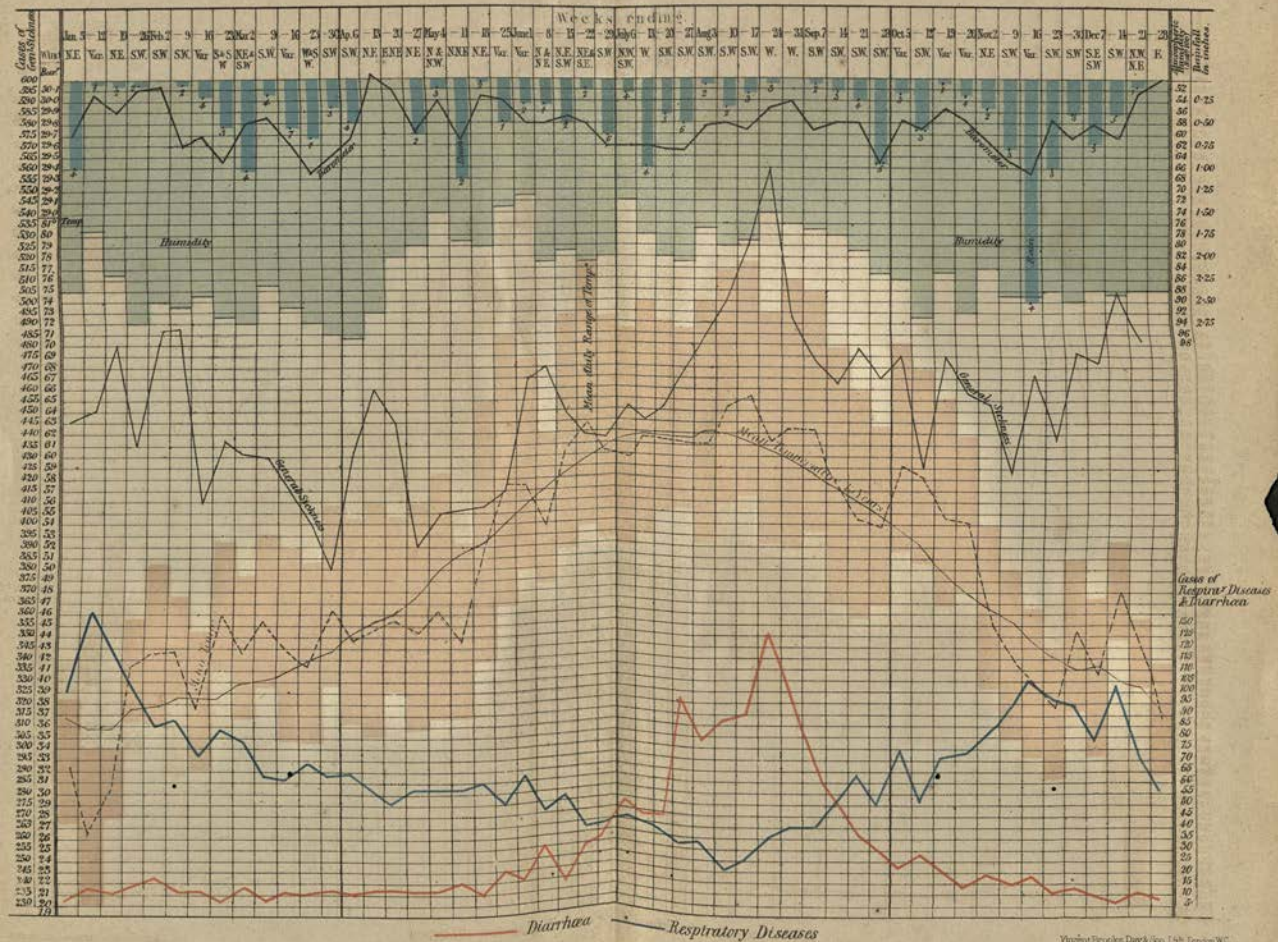

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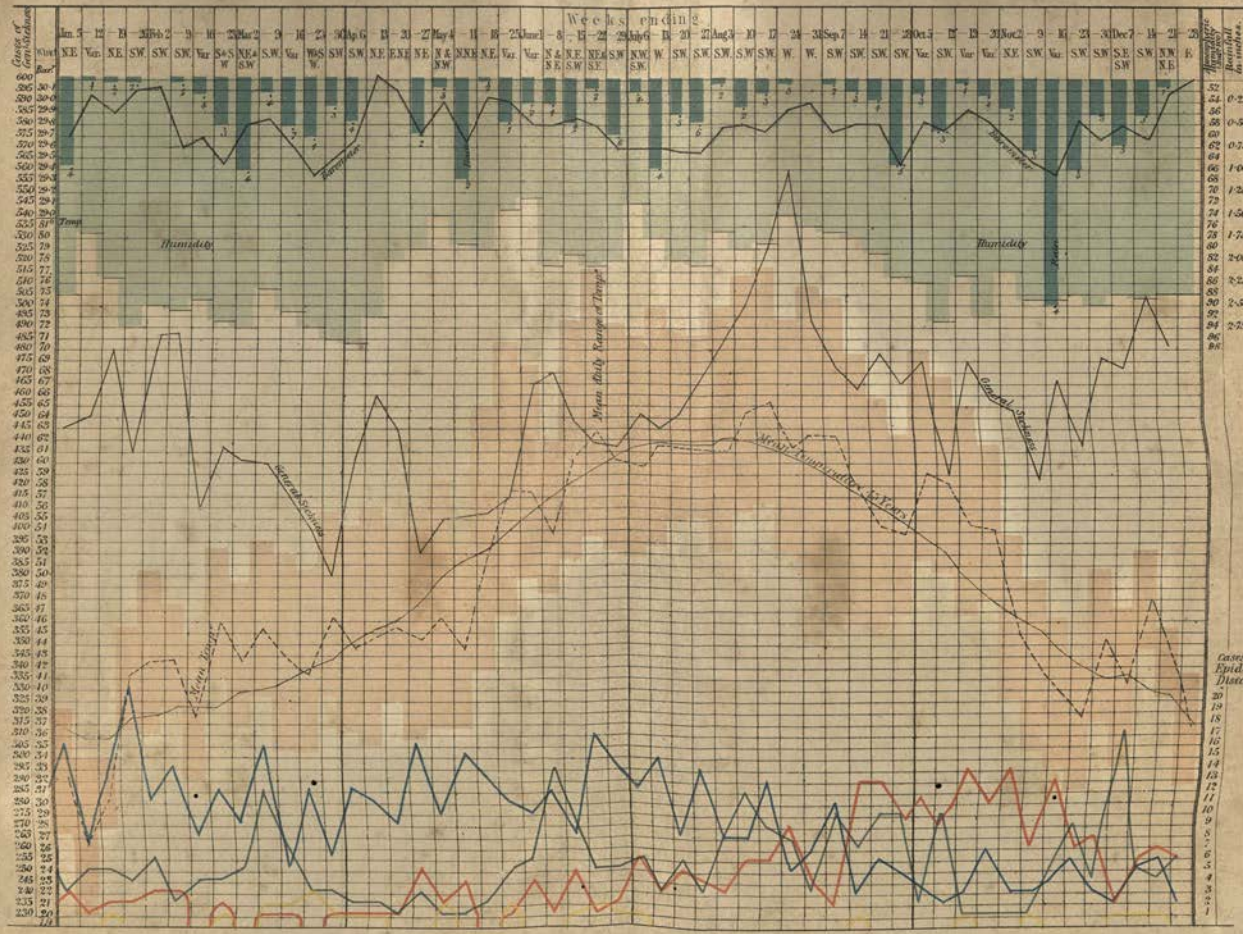

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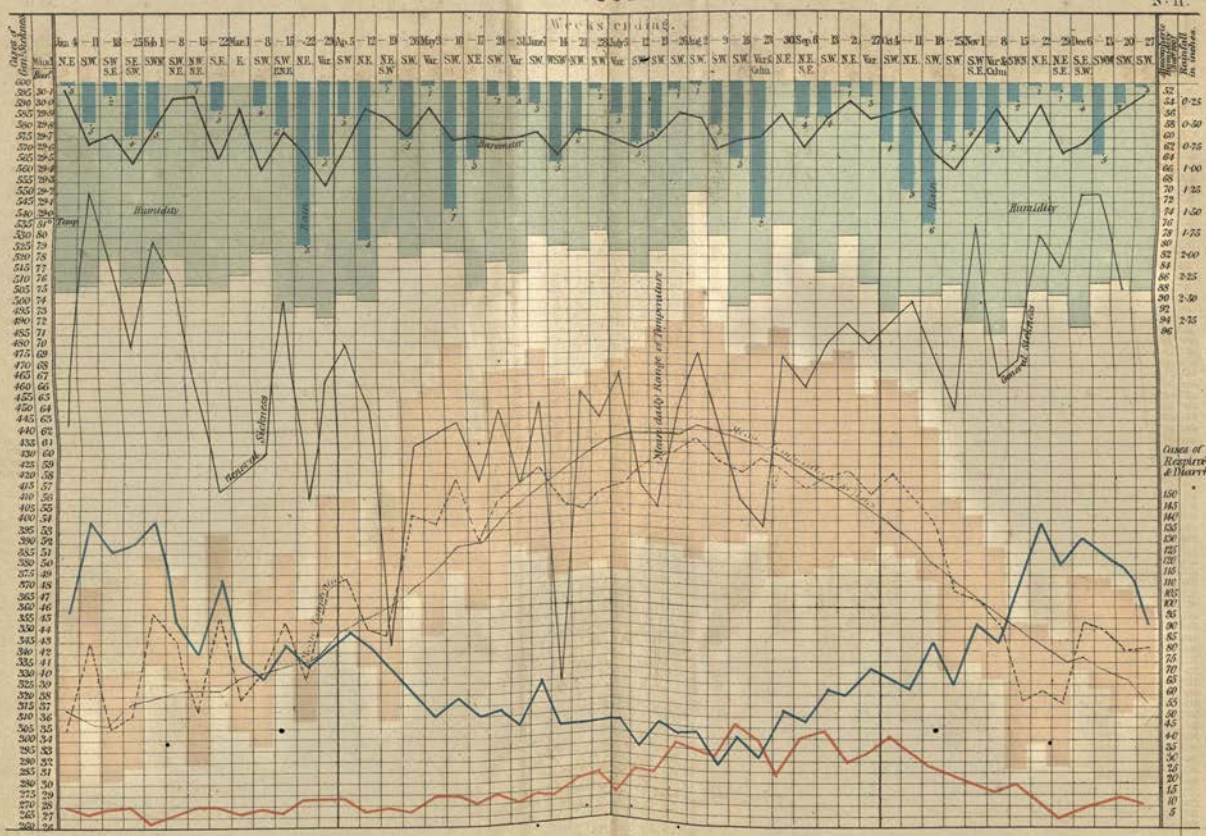
1862.



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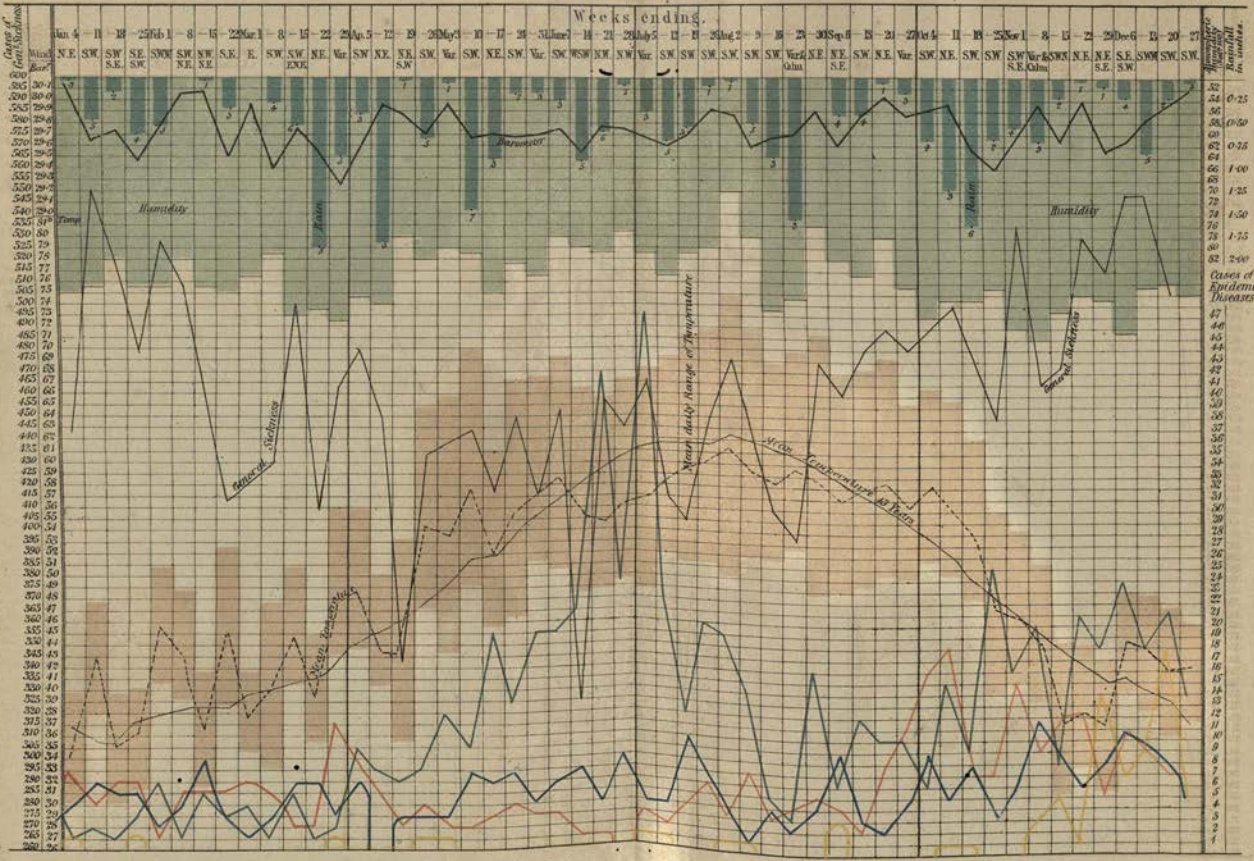
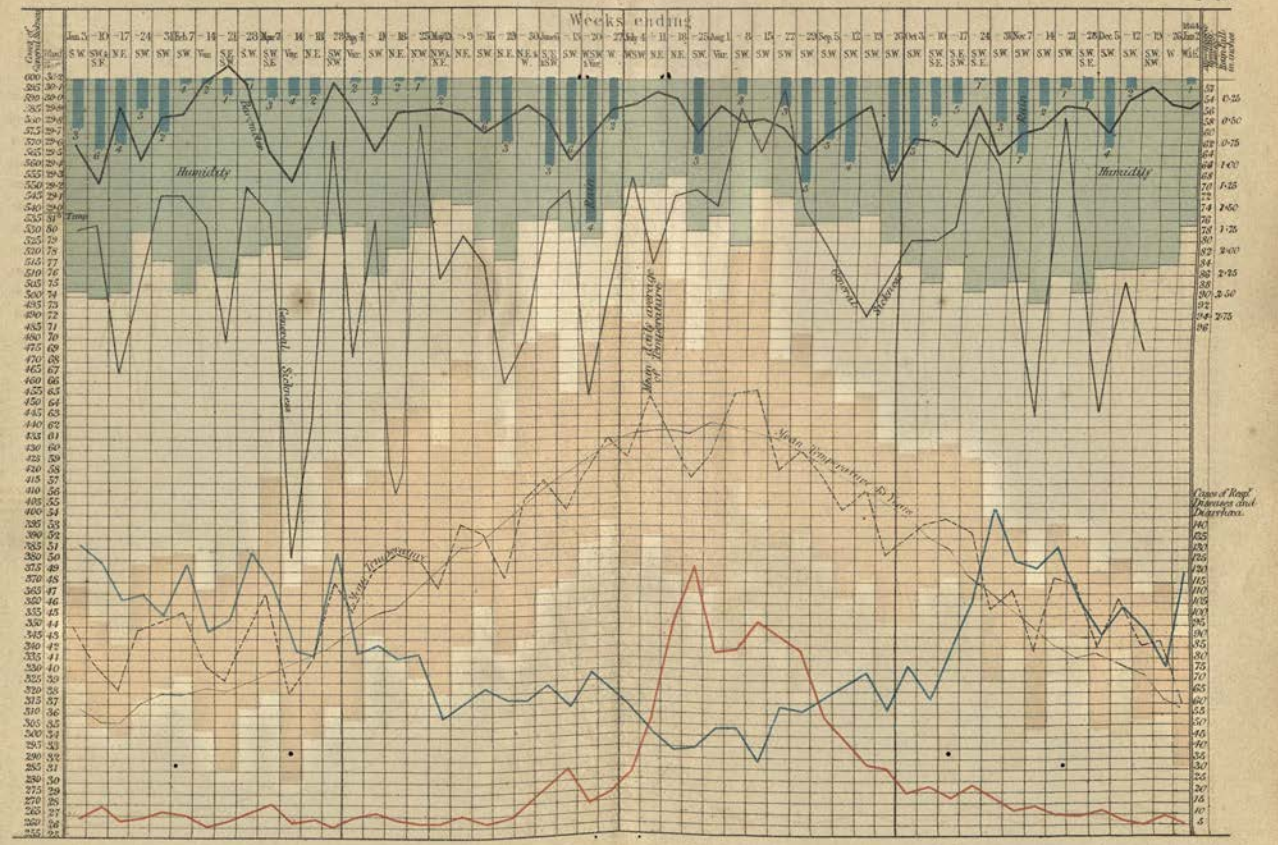


Vincent Brooks Days & Son, Lith. London W.C.

1863.

№ 13.



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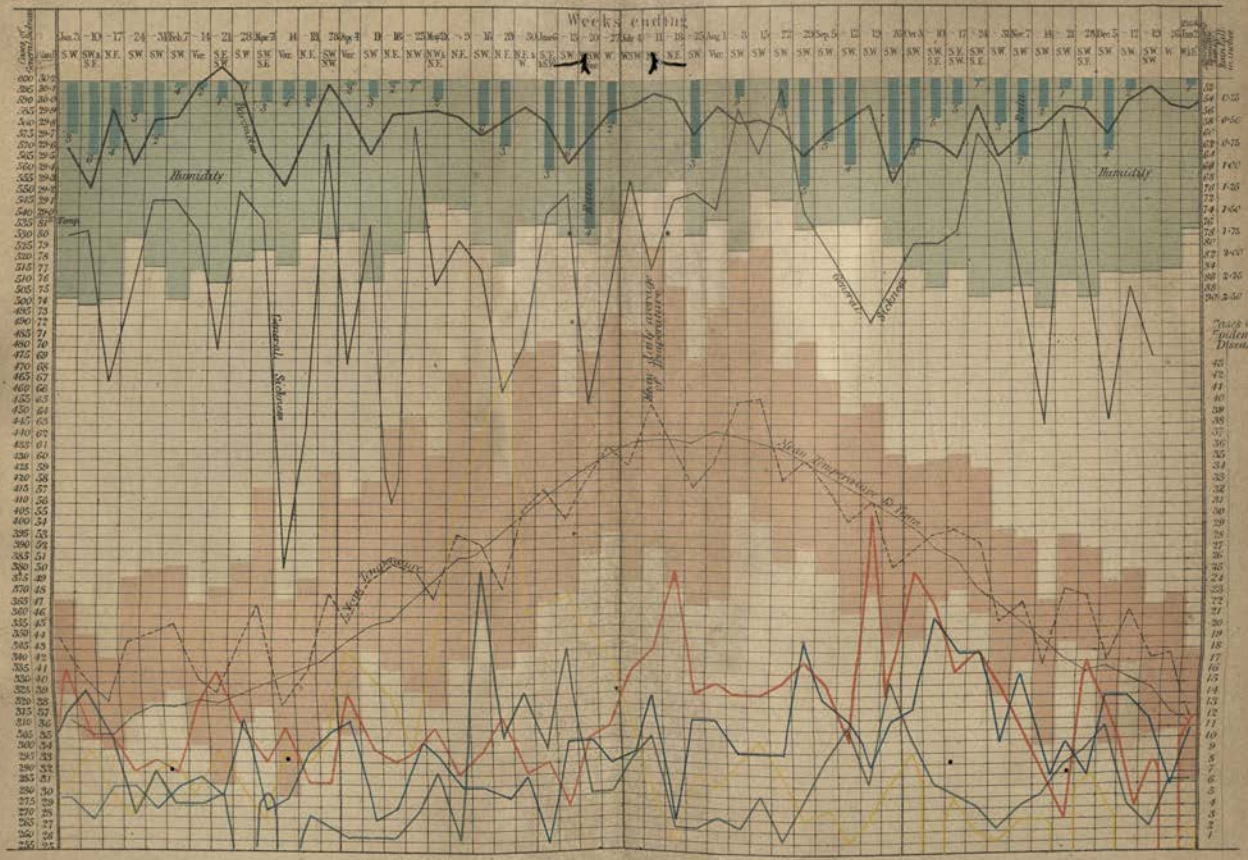

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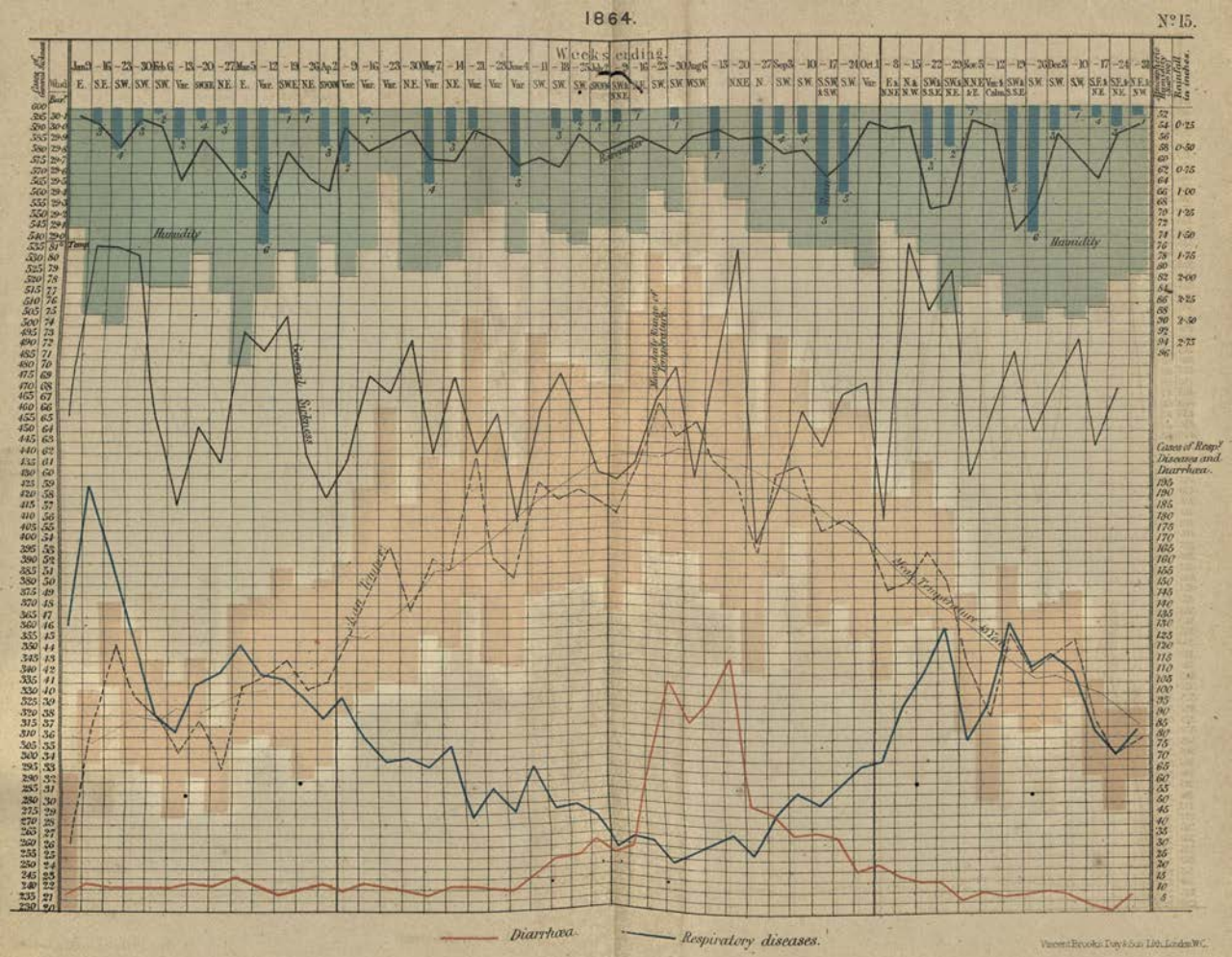

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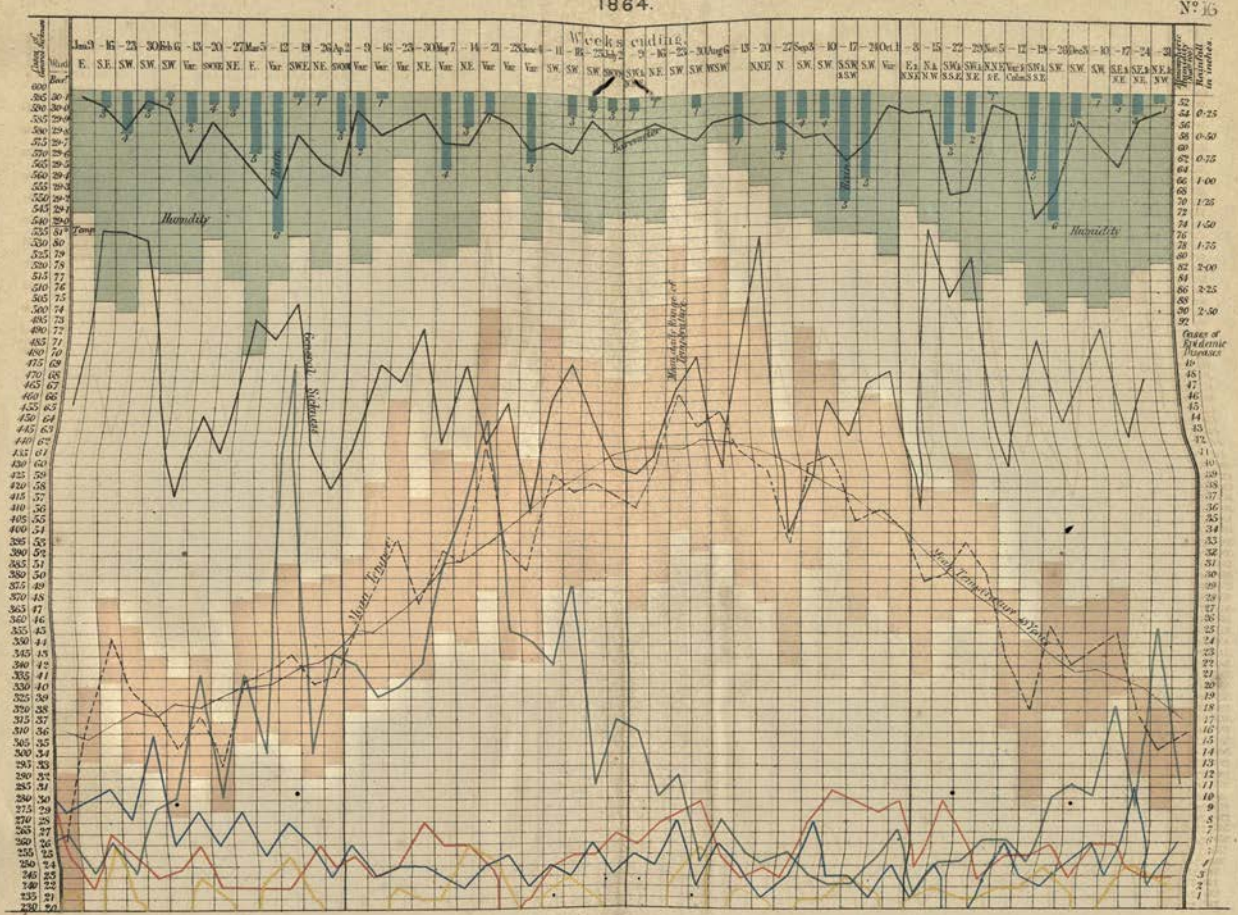

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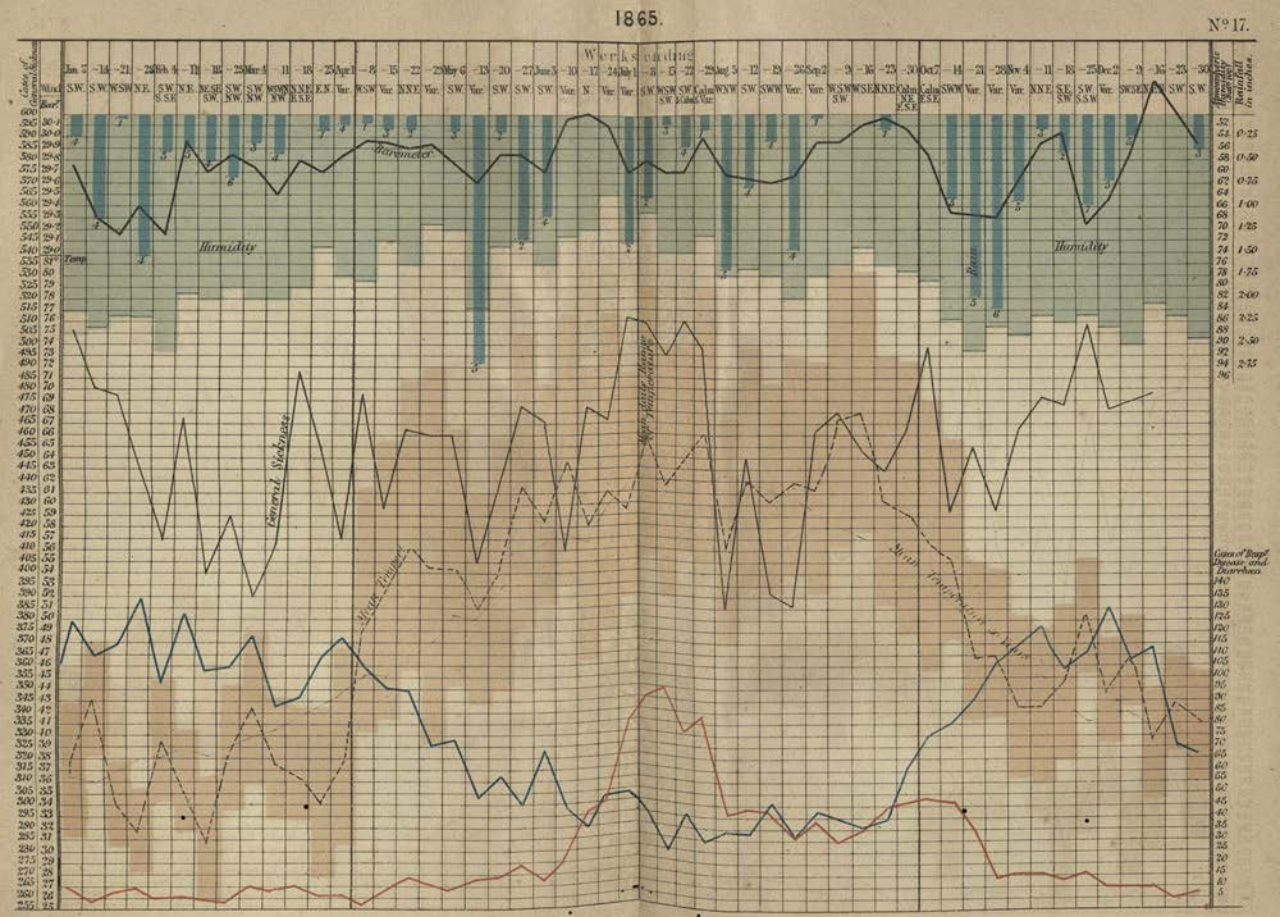

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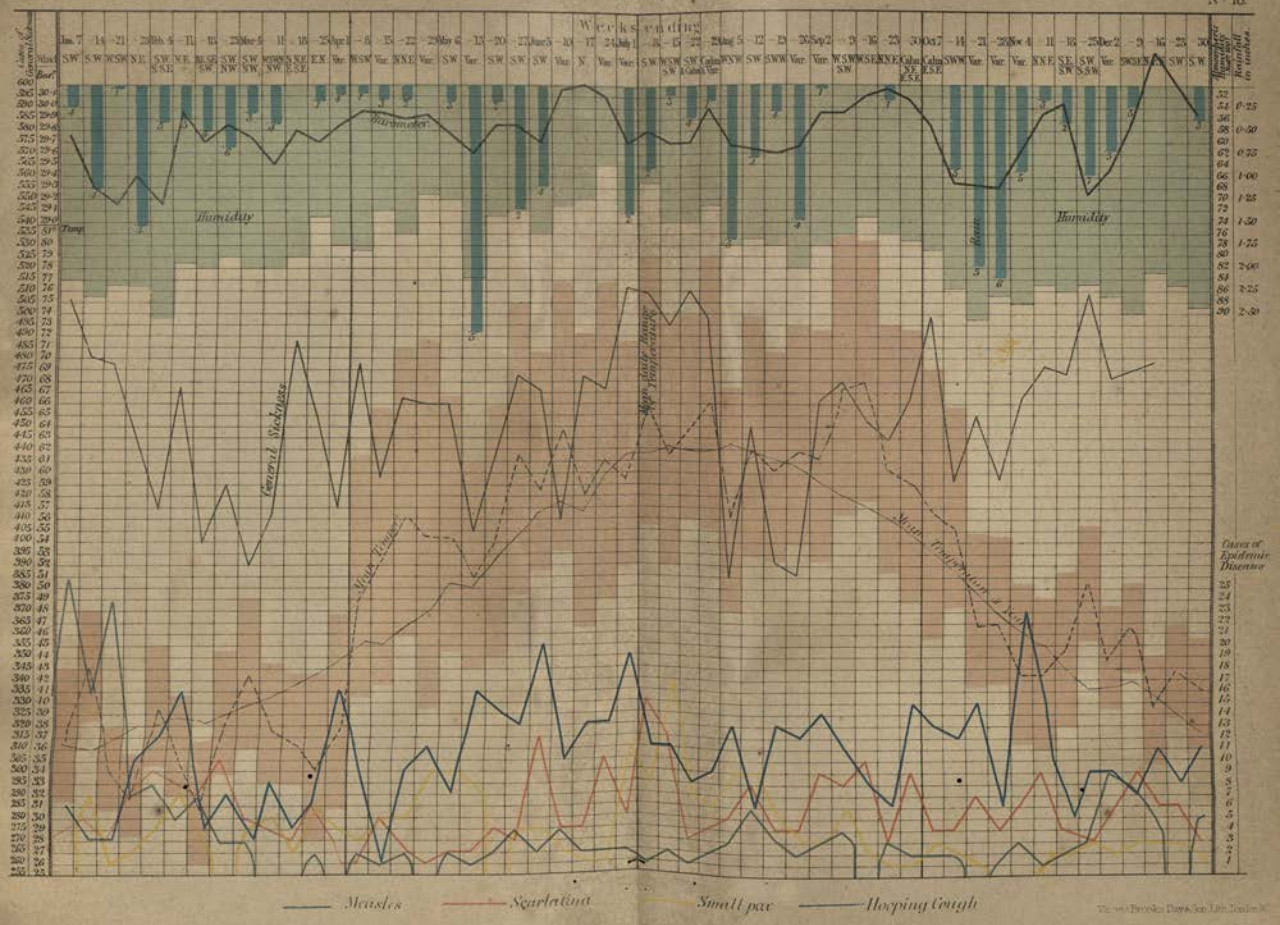
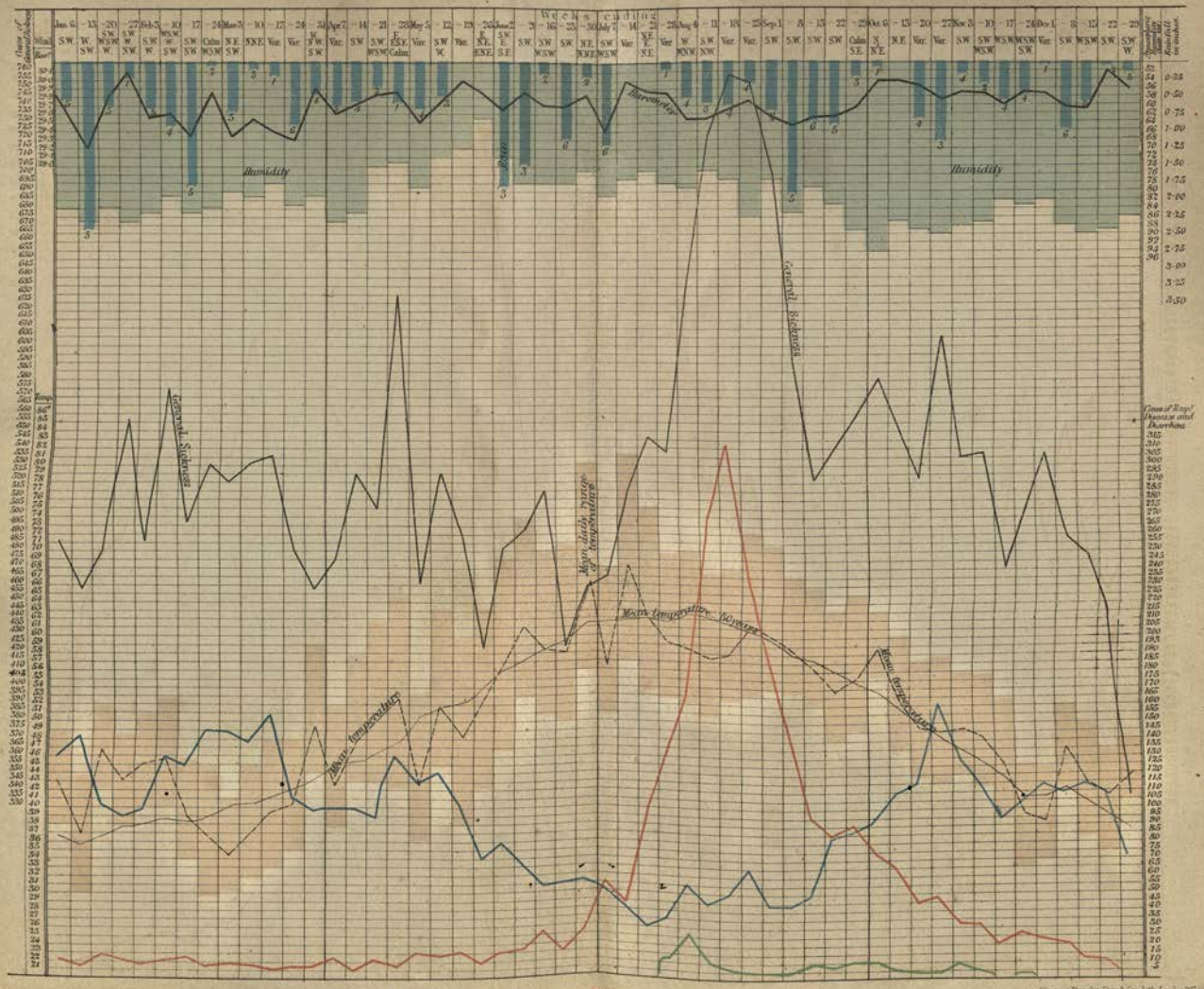
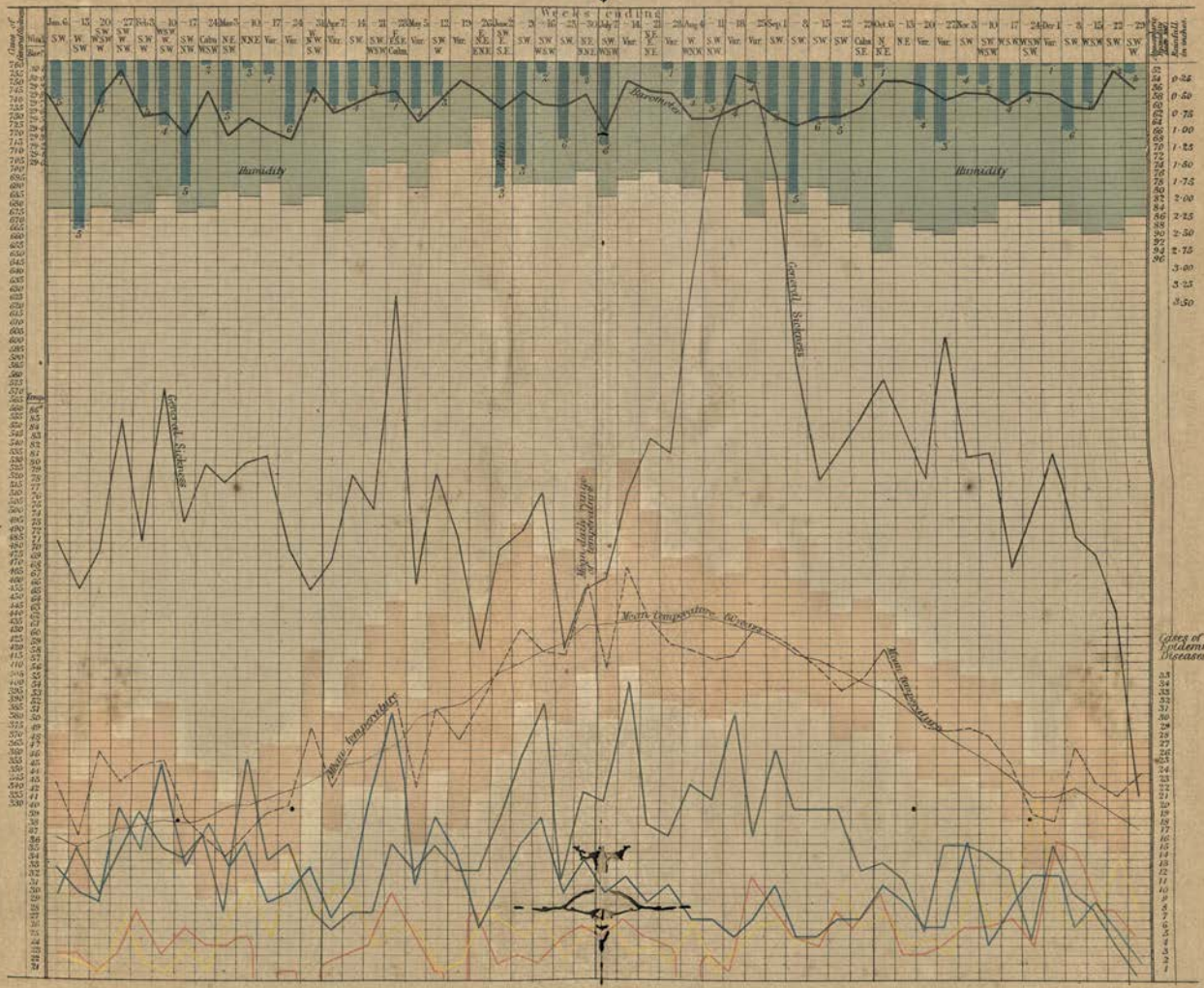

1865.
No 18.
Weeks ending
Barometer
Humidity
Rain
Humidity
General Sickness
Mean Temper
Mean Temperature & Rain
Cases of Epidemic Disease
Measles
Scarlatina
Small pox
Hooping Cough

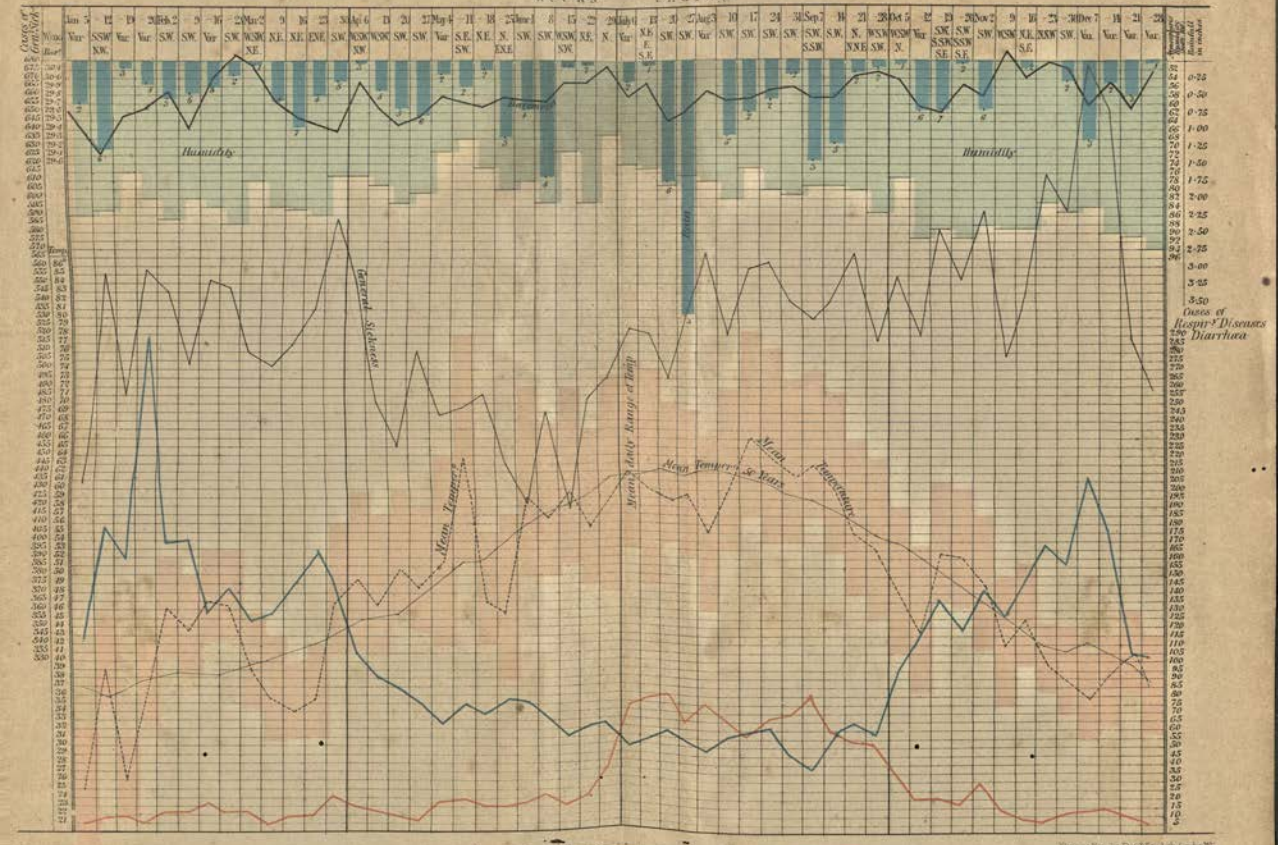

Humidity
Barometer
Humidity
Mean daily range of temperature
Mean temperature 30 years
Mean temperature
Mean temperature
Cholera
Weeks
Cholera
Cholera
Cholera


1866.
No. 29.
Weeks ending
Humidity
Humidity
Barometer
General Sickness
General Sickness
Mean Temperature
Mean Temperature
Mean Temperature
Cases of Epidemic Diseases.
Measles.
Scarlatina.
Smallpox.
Hooping Cough.

1867.

Weeks ending

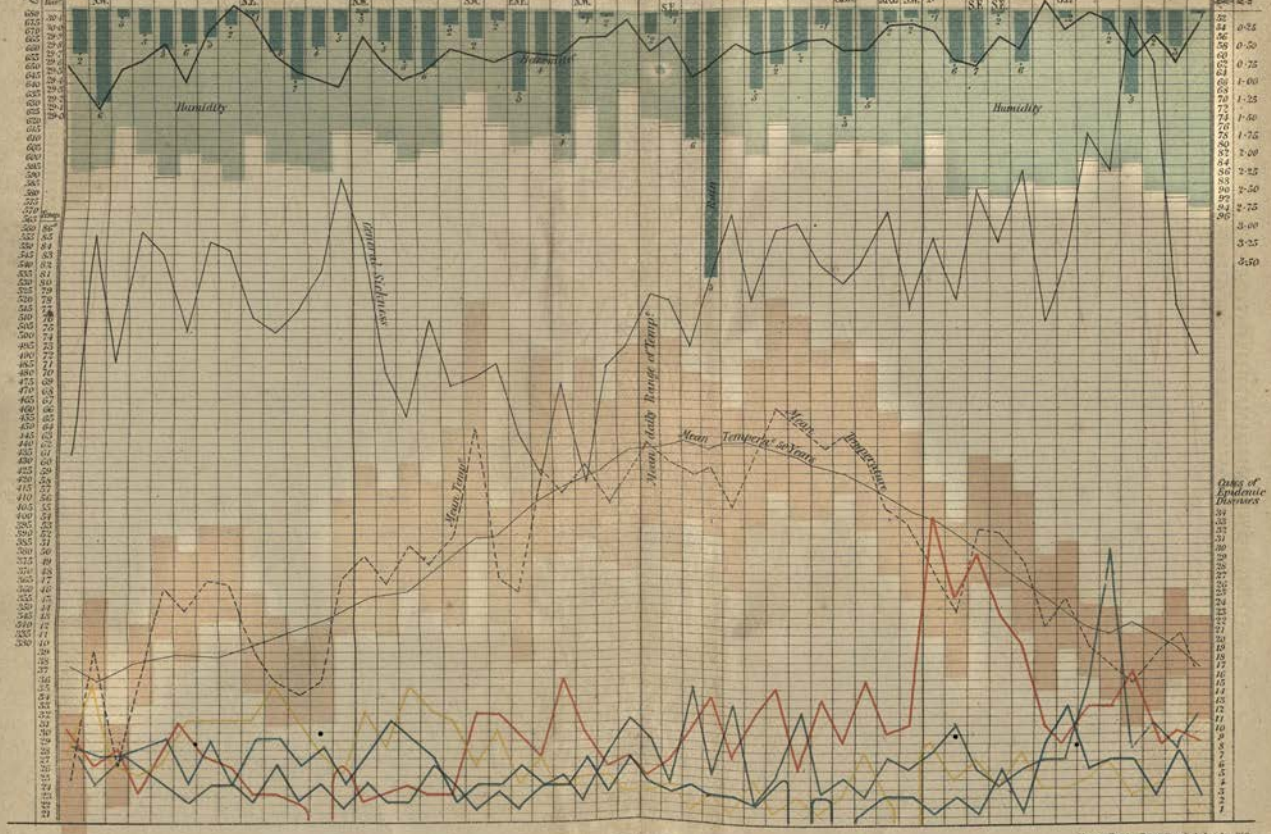
№ 21.



Vincent Brooks, Day & Son, Lith. London W.C.

1867.

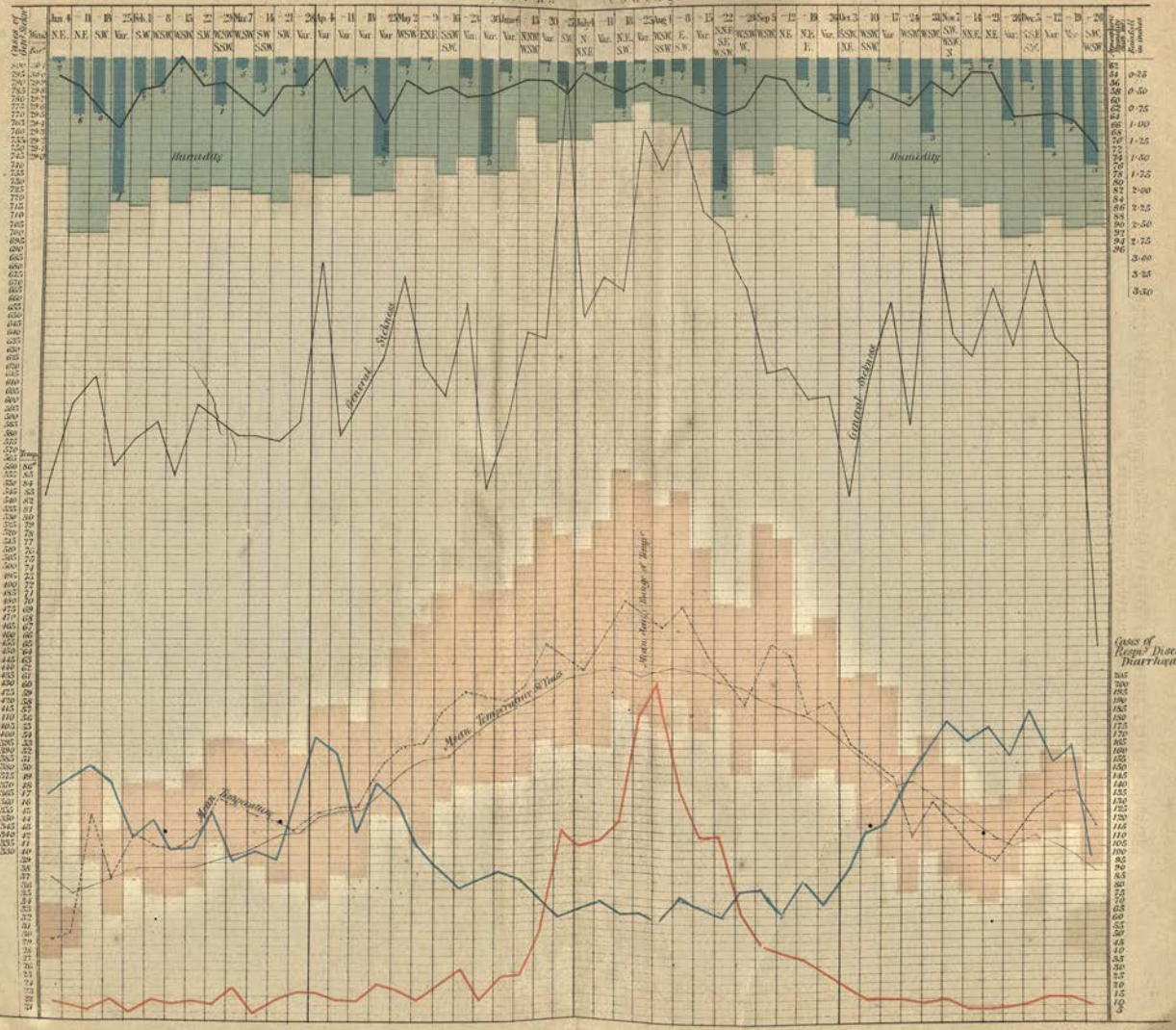
Weeks ending.



Vincent Brooks Day & Son Lith. London W.C.

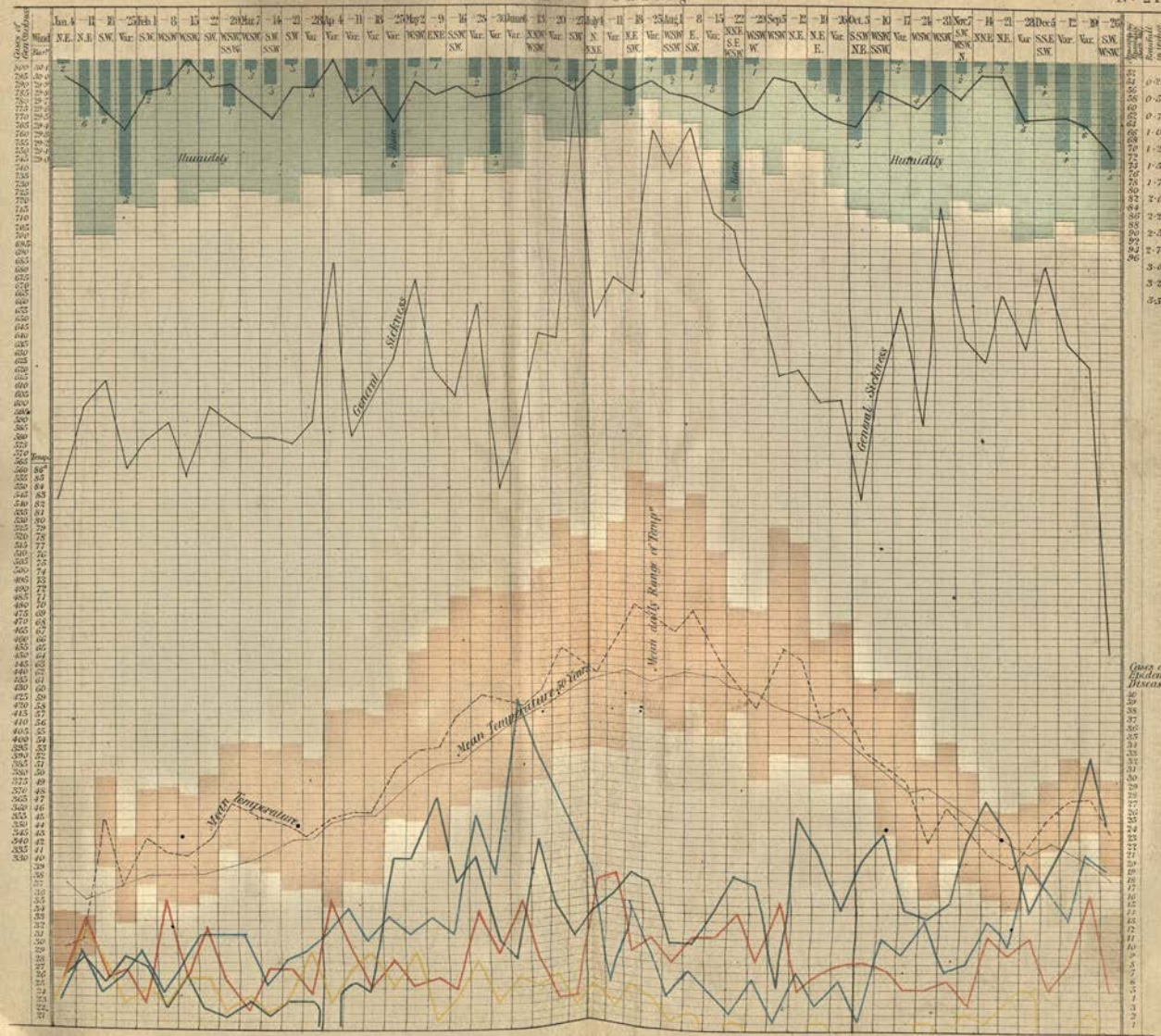
1868.

Weeks ending.



Vincent Brooks Day & Son Lith. London W.

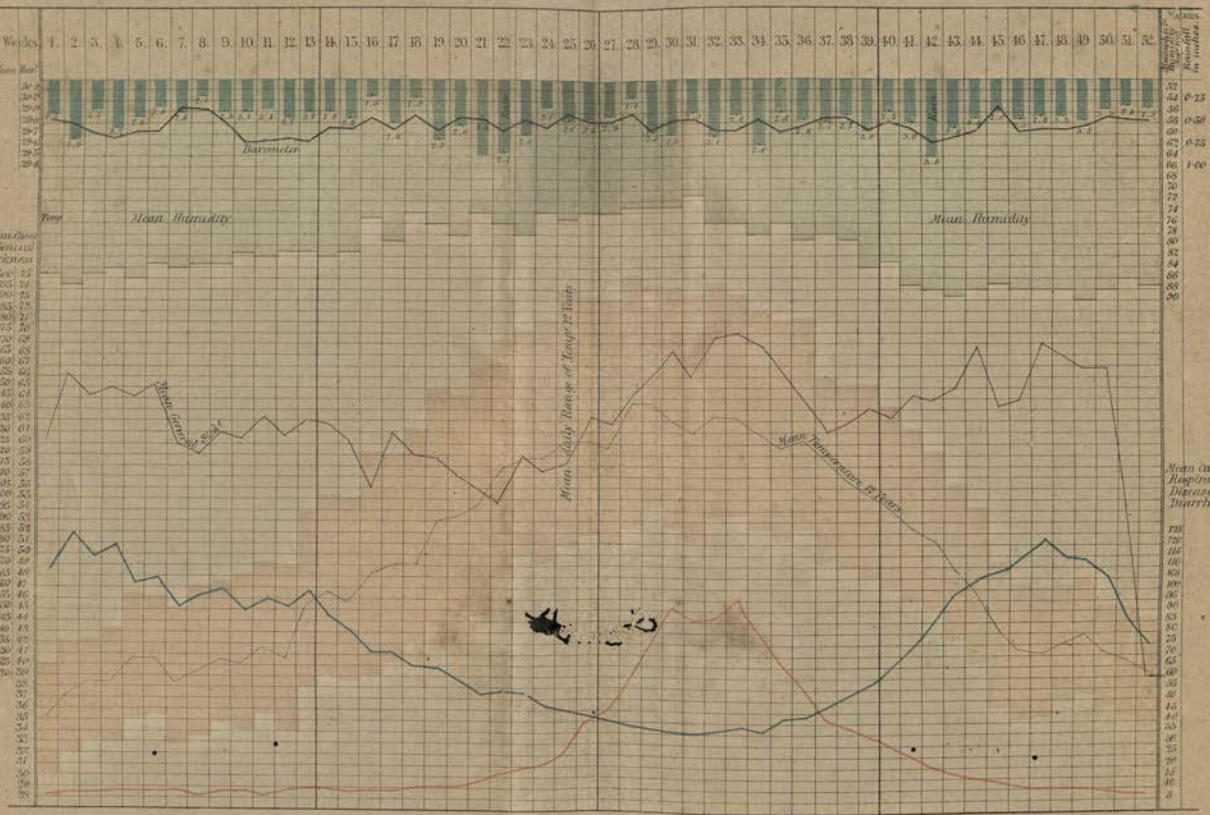
Weeks ending.



Vincent Brooks, Day & Son, Lith. to H.C.

SUMMARY OF 12 YEARS.

No. 25.



Vincent Brooks Day & Son, Lith. London W.C.

SUMMARY OF 12 YEARS.

No. 26.

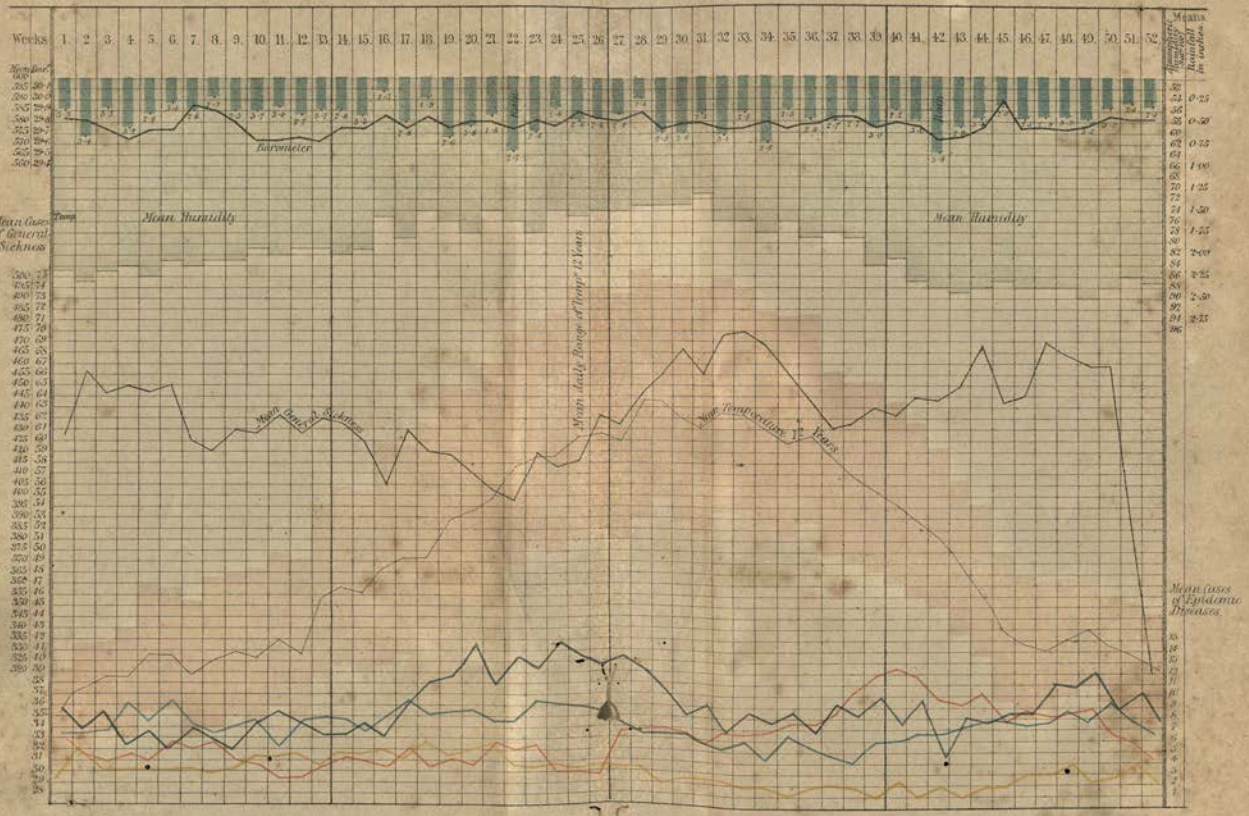


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TABLE V.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Scarlatina.						Of less Prevalence of Scarlatina.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1858 -	72	61·0	74	5·39	29	1857 -	33	63·3	77	5·73	30
1859 -	103	62·0	73	7·10	33	1860 -	67	56·3	85	9·12	52
1863 -	217	59·1	74	5·18	27	1861 -	84	60·4	78	4·20	43
1864 -	96	59·4	71	4·37	24	1862 -	62	60·2	81	5·75	33
1865 -	94	62·5	75	6·41	29	1866 -	69	58·7	80	7·93	45
1867 -	136	59·7	78	11·40	35						
1868 -	141	64·1	70	4·40	23						
Mean -	122	60·1	74	6·32	28	Mean -	63	59·6	80	6·54	41

AUTUMN QUARTERS.

1859 -	221	43·0	87	7·18	48	1857 -	25	47·4	92	5·56	23
1861 -	116	46·4	88	7·23	35	1858 -	68	43·5	87	3·11	31
1862 -	135	45·6	89	7·04	40	1860 -	53	42·8	89	4·59	35
1863 -	165	47·3	86	4·48	34	1864 -	65	43·6	82	4·13	29
1867 -	222	43·1	87	4·52	37	1865 -	71	46·1	88	8·92	37
1868 -	99	45·8	87	8·61	48	1866 -	95	46·5	87	5·36	48
Mean -	159	45·2	87	6·51	40	Mean -	62	45·0	87	5·27	33

In 1861	472 cases,	or 20·2	per 1,000	of all cases.
„ 1862	279	„ 11·6	„	„
„ 1863	481	„ 18·0	„	„
„ 1864	256	„ 10·6	„	„
„ 1865	528	„ 22·5	„	„
„ 1866	586	„ 21·3	„	„
„ 1867	270	„ 9·8	„	„
„ 1868	595	„ 18·1	„	„

There is no indication here of a cyclical recurrence of the disease such as was noted in respect of measles and scarlatina.

Diagram 26 shows the line of the distribution of hooping cough on the whole through the several seasons of the year. It resembles the line of measles in presenting two waves—a larger one culminating in the month of June, and a smaller one in the month of December. There are, however, between the two waves these differences, viz., 1st, that although they correspond in this respect, the waves of hooping cough seem to anticipate a little those of measles; and 2nd, that the waves are less pronounced, this being due to a more uniform distribution of the disease than is observed with measles.

The following represents the mean distribution of hooping cough through the several seasons of the year, as per 100 cases:—

In January	8·4	Winter quarter, 25·6 cases.
„ February	8·9	
„ March	8·3	
„ April	9·2	Spring quarter, 28·7 „
„ May	9·3	
„ June	10·2	
„ July	7·6	Summer quarter, 20·0 „
„ August	6·1	
„ September	6·3	
„ October	7·6	Autumn quarter, 25·7 „
„ November	8·8	
„ December	9·3	
	100·0	1·00

The autumn and winter quarters appear to be alike in respect of the prevalence of hooping cough. The spring quarter is that in which I have observed that the disease prevails most, and the summer that in which it prevails least. The largest proportion of cases was observed to occur in the whole in the month of June, and the smallest in the months of August and September. The short period of time which elapses between the period of greatest and least prevalence is remarkable, the decline of the disease as summer comes on being very sudden.

The following represents the average meteorological conditions of the weeks about the period of the spring rise and subsequent sudden fall, and of the autumnal rise. I assume about a week as the period of incubation; probably it is something less than this, but it is not likely that medical aid would be sought until the disease was tolerably pronounced. I allow a week, then, in the table as a fair correction. I begin from the twelfth week of the year, thus to correspond with the last week of the winter quarter.

—	Average of new Cases, One Week later.	Mean Temperature.	Mean daily Range of Temperature.	Mean Humidity.	Mean Rainfall.	Rainy Days, 12 Years.
		°	°		Inches.	
12th week	8·0	40·9	15·0	81	0·41	33
13th „ -	7·7	45·4	15·8	81	0·38	45
14th „ -	6·6	46·6	17·4	82	0·38	34
15th „ -	*8·2*	*46·6*	*17·4*	*81*	*0·44*	*40*
16th „ -	9·6	48·2	20·3	75	0·14	19
17th „ -	8·1	49·1	18·9	79	0·50	32
18th „ -	8·3	49·2	19·2	74	0·22	23
19th „ -	8·5	52·9	21·3	76	0 67	35
20th „ -	7·8	53·7	19·6	78	0·53	32
21st „ -	7·7	54·8	22·2	74	0·44	20
22nd „ -	*9·5*	*57·8*	*21·1*	*76*	*0·82*	*33*
23rd „ -	9·3	58·5	20·5	78	0·63	32
24th „ -	9·4	58·8	21·8	74	0·35	26
25th „ -	*8·6*	*60·2*	*22·0*	*75*	*0·47*	*32*
26th „ -	7·2	60·4	20·7	74	0·48	32
27th „ -	6·5	59 9	21·5	74	0·40	29
28th „ -	6·5	63·6	23·7	73	0·23	17
29th „ -	6·5	63·5	20·2	73	0·59	30
30th „ -	5·6	62·0	21·4	73	0·63	25
31st „ -	5·3	61·1	22·4	71	0·39	28
32nd „ -	6·0	62·4	21·2	76	0·65	38
33rd „ -	4·3	62·2	20·0	76	0·40	34
34th „ -	6·8	60·8	19·3	78	0·74	34
35th „ -	5·9	59·8	19·9	76	0·38	31
36th „ -	4·8	60·3	18·9	79	0·48	34
37th „ -	4·2	58·7	16·3	78	0·50	33
38th „ -	*6·0*	*56·7*	*16·2*	*79*	*0·40*	*33*
39th „ -	6·2	55·5	17·1	84	0·55	37
40th „ -	6·8	54·5	16·2	83	0·37	27
41st „ -	6·7	52·5	15·1	87	0·50	37
42nd „ -	6·9	51·2	14·3	88	0·87	46
43rd „ -	7·6	48·8	14·1	89	0·54	35
44th „ -	8·0	46·7	14·8	88	0·47	41

From which it appears that, 1st. The spread of hooping cough is promoted by a mean temperature above 46°, and especially by a temperature between 57° and 60°. 2d. That a mean temperature above 60° is very unfavourable to the disease, and distinctly promotive of its decline when epidemic. 3d. That a mean temperature below 40° is also less favourable than one between 40° and 46°, but more favourable than a mean temperature above 60°. I have had some reason to suspect that a high barometric pressure is favourable to the occurrence of the convulsive affections of children, but there is no connexion traceable between this and the extension of hooping cough.

Table VI. shows for each quarter the more important meteorological conditions of the seasons in which hooping cough was more or less prevalent. From this it appears, 1. That in all seasons of the year, with the exception of autumn, the extension of hooping cough is promoted by a comparatively warm and dry atmosphere; in the autumn a warm and moist season appears to be most favourable to it. 2. In the spring and summer the unfavourable influence of atmospheric moisture and much rain is especially obvious. Great atmospheric dryness and little rainfall appear capable of counteracting to some extent the operation of a temperature above 60°, as in the summer of 1868. (See Table VI., pp. 70, 71.)

TABLE VI.

WINTER QUARTERS.

Of greater Prevalence of Hooping Cough.						Of less Prevalence of Hooping Cough.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1858	95	37·9	81	3·41	20	1857	41	36·3	85	3·79	35
1859	123	43·3	83	2·55	33	1860	40	38·9	82	3·80	52
1861	150	39·7	89	4·96	40	1862	56	40·6	86	5·73	43
1864	106	38·2	82	4·27	37	1863	83	42·5	83	4·08	35
1865	98	36·6	82	5·94	45	1867	92	38·5	83	6·29	51
1866	184	41·2	83	9·55	51	1868	97	41·1	82	6·52	46
Mean -	126	39·9	83	5·11	37	Mean -	68	39·6	84	5·03	43

SPRING QUARTERS.

1858	125	54·7	72	5·07	30	1857	61	54·3	76	4·06	31
1861	158	51·6	81	4·73	30	1859	55	54·2	77	6·40	29
1865	154	56·3	72	7·24	24	1860	45	50·5	80	10·36	49
1866	193	52·9	75	8·00	35	1862	64	53·1	82	7·61	46
1868	248	55·1	74	4·22	21	1863	90	52·6	77	5·99	34
						1864	49	53·5	73	3·48	22
						1867	76	54·3	77	6·27	39
Mean -	175	54·1	75	5·85	27	Mean -	62	53·2	78	6·31	35

TABLE VI.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Hooping Cough.						Of less Prevalence of Hooping Cough.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1858	58	61·0	74	5·39	29	1857	46	63·3	77	5·73	30
1861	115	60·4	78	4·20	43	1859	27	62·8	73	7·10	33
1863	142	59·1	74	5·18	27	1860	51	56·3	85	9·12	52
1865	137	62·5	75	6·41	29	1862	59	60·2	81	5·75	33
1866	103	58·7	80	7·93	45	1864	52	59·4	71	4·37	24
1868	89	64·1	70	4·40	23	1867	34	59·7	78	11·40	35
Mean -	107	61·0	75	5·58	32	Mean -	44	60·3	78	7·24	34

AUTUMN QUARTERS.

1857	70	47·4	92	5·56	23	1859	54	43·0	87	7·18	48
1858	94	43·5	87	3·11	31	1861	49	46·4	88	7·23	35
1860	128	42·8	89	4·59	35	1864	49	43·6	82	4·13	29
1862	100	45·6	89	7·04	40	1867	68	43·1	87	4·52	37
1863	166	47·3	86	4·48	34						
1865	139	46·1	88	8·92	46						
1866	106	46·5	87	5·36	41						
1868	161	45·8	87	8·61	48						
Mean -	120	45·6	88	5·95	37	Mean -	44	44·0	86	5·76	37

Small Pox.

The 1,977 cases of small pox were distributed through the 12 years thus :—

In 1857	- 28	or	2·1	per 1,000 of all cases.	
„ 1858	- 42	„	3·0	„	„
„ 1859	- 65	„	4·3	„	„
„ 1860	- 138	„	6·3	„	„
„ 1861	- 27	„	1·1	„	„
„ 1862	- 76	„	3·1	„	„
„ 1863	- 488	„	18·2	„	„
„ 1864	- 89	„	3·7	„	„
„ 1865	- 209	„	8·9	„	„
„ 1866	- 318	„	11·5	„	„
„ 1867	- 329	„	12·0	„	„
„ 1868	- 168	„	5·1	„	„

We have to note here a gradual increase of small pox year by year from 1857 to 1860, when it exhibited an approach to epidemic prevalence; then a sudden reduction in the next year, 1861, an increase in 1862, and the grand epidemic outburst of 1863. Again, in the year after the epidemic, in 1864, a diminution of small pox about proportional to what took place after 1860. Since 1864 small pox has been increasing in prevalence year by year until 1868, when in the middle of August it almost abruptly died away from among our population. From the second week in August until the second week in November only three cases, at long intervals, were recorded in the books to which I had access. A prolonged freedom from small pox such as this had not occurred in Islington since the middle of 1862. I may say here, by way of anticipation, that in no week of all the 11 years prior to 1868 did the mean temperature of any week exceed 71°, and that temperature only was attained in the 28th week of 1859; nor in any week prior to 1868 did the mean of the highest day temperature reach above 86°, and that was in the same week. In the four weeks of July 1859 the means of the maximum temperatures were 81·4°, 86·5°, 82·6°, and 79·0°. Nothing approaching so prolonged a high temperature in the daytime occurred again until last year. In the second week of July 1868, the mean of the maximum temperatures of the week was 79·8°; in the third, 86·0°; in the fourth, 84·4°; in the first week of August, 81·7°; and in the second, 83·6°. The mean temperature of the third week of July was 70·7°; of the fourth, 69·2; of the first week of August, 67·6°; and of the second, 69·8°.

Whatever, then, the causes may have been which for so many years past have fostered small pox, the cause of the disappearance of the disease in August last is scarcely possible to be overlooked. The efforts made since 1863 to render the vaccination of our population more complete and perfect have probably saved us, during 1866 and 1867, from an epidemic more serious even than that of 1863, which itself was three times more serious than that of 1860; but it is clear that the cessation of the plague has been the result of climatic conditions.

Diagram 26 shows the seasonal line of small pox as it has pursued its course on the average of the 12 years. Small pox, like scarlatina, forms but one wave in the course of the year. Its prevalence in the several months and quarters may be represented thus per 100 cases :—

In January	8·7	Winter quarter, 27·1 cases.	
„ February	8·0		
„ March	10·4		
„ April	11·8	Spring quarter, 35·8 „	
„ May	14·3		
„ June	9·7		
„ July	7·2	Summer quarter, 17·9 „	
„ August	6·1		
„ September	4·6		
„ October	4·6	Autumn quarter, 19·2 „	
„ November	6·7		
„ December	7·9		
	100·0		1·00

The rule has been for small pox to prevail least in the summer, to increase through the autumn and winter, and to prevail most in the spring of the year. The smallest number of cases on the whole was observed in the months of September and October; the wave rose gradually through the succeeding months (with a slight check in February), to attain its highest point in the month of May. From this point it sank rapidly through July and August, to attain its lowest point again in September. Small pox is therefore clearly a disease the extension of which is promoted by cold weather and checked by hot weather.

In any consideration of its association with conditions of weather an allowance of about a fortnight must be made for the incubation of the disease.

On the average of the 12 years we may regard the disease at its lowest point in the month of October, and the commencing increase to have taken place about the first week in November. The meteorological conditions on the mean of the 12 years about this time were as follows:—

—	Average of new Cases Two Weeks later.	Mean Temperature.	Mean daily Range of Temperature.	Mean Humidity.	Mean Rainfall.	Rainy Days, 12 Years.
		°	°		Inches.	
39th week	1·2	55·5	17·1	84	0·55	37
40th „	1·9	54·5	16·2	83	0·37	27
41st „	1·2	52·5	15·1	87	0·50	37
42nd „	1·8	51·2	14·3	88	0·87	46
43rd „	2·0	48·8	14·1	89	0·54	35
44th „	3·1	46·7	14·8	88	0·47	41
45th „	3·1	43·0	13·1	87	0·30	24
46th „	3·9	41·6	12·7	88	0·49	30

Small pox, then, may be considered as beginning to extend when the temperature at the commencement of the autumn begins to fall to about 50°, after which the disease becomes more and more prevalent as the temperature continues to sink, and again as beginning to rise towards the spring of the year. On the average of years the largest number of cases was observed in the 21st week of the year, immediately after which, in the 22d week, the number of cases fell remarkably. The

following are the means of the meteorological conditions of the several weeks about this time :—

—	Average of new Cases Two Weeks later.	Mean Temperature.	Mean daily Range of Temperature.	Mean Humidity.	Mean Rainfall.	Rainy Days, 12 Years.
		°	°		Inches.	
17th week	4·6	49·1	18·9	79	0·50	32
18th „	5·0	49·2	19·2	74	0·22	23
19th „	6·5	52·9	21·3	76	*0·67*	35
20th „	3·9	53·7	19·6	78	0·53	32
21st „	3·6	54·8	22·2	74	0·44	20
22nd „	3·7	57·8	21·1	76	0·82	33
23rd „	3·4	58·5	20·5	78	0·63	32
24th „	3·6	58·8	21·8	74	0·35	26
25th „	3·2	60·2	22·0	75	0·47	32
26th „	3·2	60·4	20·7	74	0·48	32
27th „	2·0	59·9	21·5	74	0·40	29

Reading this with the preceding table, it appears that the mean temperature of about 52° is that which marks off the conditions favourable or unfavourable to the extension of small pox. A temperature below this promotes its spread, and a temperature above it tends to check its spread. It is clear, however, that this observation can only apply to the country in which it has been made, or to one presenting similar climatic conditions.

Table VII. shows the more important meteorological conditions which were existent in the several quarters in which small pox was more or less prevalent. (See Table VII., pp. 75, 76.) From which it appears :—

1. That with the exception of the spring and summer quarters, in the latter of which excessive heat is apt to check the spread of the disease, small pox is promoted by a comparatively warm season.
2. That in all seasons of the year comparative atmospheric dryness is more conducive to the spread of small pox than comparative humidity of the atmosphere.
3. That in every season except the autumn, there was on the whole a greater rainfall in the years of greater prevalence of small pox than in those of its lesser prevalence.

I may add further, that making the fortnight's allowance for incubation, great rises or falls of temperature appear to promote the extension of small pox in seasons when it prevails. In this it resembles measles.

The alleged connexion between epidemics of small pox and measles may be studied upon the diagrams.

1. As regards the slighter small pox outbreak of 1860, it is observable that although 1859 was not a year on which an epidemic of measles was due, yet, for a non-epidemic year, the disease was unusually prevalent during the three first quarters; it subsided during the autumn, and small pox broke out in the first month of 1860. As small pox subsided in May and June, measles again became severely epidemic.

2. In 1862 a heavy epidemic of measles occurred, the principal violence of the outbreak being expended upon the months of June and July. It subsided through August and September. In November the grand epidemic of small pox commenced, the disease spreading extensively in the month of December. In November and December measles became concurrently active. It subsided, however, as small pox gained

TABLE VII.

WINTER QUARTERS.

Of greater Prevalence of Small Pox.						Of less Prevalence of Small Pox.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfal.	Rainy Days.
		°		Inches.				°		Inches.	
1860	58	38·9	82	3·80	52	1857	5	36·3	85	3·79	35
1863	88	42·5	83	4·08	35	1858	13	37·9	81	3·41	20
1866	66	41·2	83	9·55	51	1859	16	43·3	83	2·55	33
1867	121	38·5	83	6·29	51	1861	32	39·7	89	4·96	40
1868	65	41·1	82	6·52	46	1862	3	40·6	86	5·73	43
						1864	22	38·2	82	4·27	37
						1865	45	36·6	82	5·94	45
Mean -	79	40·4	83	6·04	47	Mean -	19	38·9	84	4·37	36

SPRING QUARTERS.

1860	37	50·5	80	10·36	49	1857	13	54·3	76	4·06	31
1863	291	52·6	77	5·99	34	1858	3	54·7	72	5·07	30
1865	62	56·3	72	7·24	24	1859	14	54·2	77	6·40	29
1866	74	52·9	75	8·00	35	1861	10	51·6	81	4·73	30
1867	102	54·3	77	6·27	39	1862	2	53·1	82	7·61	46
1868	68	55·1	74	4·22	21	1864	23	53·5	73	3·48	22
Mean -	105	53·6	76	7·01	32	Mean -	10	53·6	77	5·22	31

TABLE VII.—*continued.*

SUMMER QUARTERS.

Of greater Prevalence of Small Pox.						Of less Prevalence of Small Pox.					
Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.	Years.	New Cases.	Mean Temperature.	Mean Humidity.	Total Rainfall.	Rainy Days.
		°		Inches.				°		Inches.	
1858	22	61·0	74	5·39	29	1857	1	63·3	77	5·73	30
1863	73	59·1	74	5·18	27	1859	13	62·8	73	7·10	33
1865	77	62·5	75	6·41	29	1860	12	56·3	85	9·12	52
1866	66	58·7	80	7·93	45	1861	2	60·4	78	4·20	43
1867	36	59·7	78	11·40	35	1862	7	60·2	81	5·75	33
						1864	19	59·4	71	4·37	24
						1868	20	64·1	70	4·40	23
Mean -	54	60·3	76	7·26	33	Mean -	10	60·9	77	5·81	34

AUTUMN QUARTERS.

1862	64	45·6	89	7·07	40	1857	4	47·4	92	5·56	23
1863	36	47·3	86	4·48	34	1858	7	43·5	87	3·11	31
1866	112	46·5	87	5·36	41	1859	13	43·0	87	7·18	48
1867	70	43·1	87	4·52		1860	12	42·8	89	4·59	35
						1861	5	46·4	88	7·23	35
						1864	25	43·6	82	4·13	29
						1865	25	46·1	88	8·92	46
						1868	15	45·8	87	8·61	48
Mean -	70	45·7	87	5·35	38	Mean -	13	44·8	88	6·16	36

strength during the early months of 1863. The chief violence of small pox in this year was expended upon the months of May and June, during which the ordinary spring increase of measles was observed. The end of 1863 and beginning of 1864 witnessed the reduction of small pox to a small number of cases, and in February measles again broke out, the commencement of a severe spring epidemic.

3. The slighter small pox epidemic of 1867 was again preceded by a heavy epidemic of measles in 1866, and its subsidence in 1868 by another heavy epidemic, lasting from May till the end of the year.

I feel that in this paper I have only skimmed the surface of a very interesting and important investigation, but perhaps it will be considered that the inferences drawn are as much as the records at my disposal suffice for. Probably a deeper study of the diagrams may suggest others; it does so to myself. The area from which the observed facts are drawn is comparatively a very limited one. I am conscious that my inferences can only therefore be regarded as provisional. I am aware of but very few places in which a regular registration of sickness among the poor has been attempted, and of no place where it has been steadily carried on for so many as 12 years, except in Islington. But I think I have indicated the important scientific results which would follow were a national registration of sickness established. I can testify from experience how small the amount of labour would be in effecting such a registration in each district of the kingdom. At the present time there exist everywhere abundant materials in the books kept by poor law medical officers, and at the various public institutions for the relief of sickness, but they are unused because it is nobody's business to collect them together. Were this done it would be possible to distinguish between the liability of different districts to diseases of certain kinds, and the difference in fatality which attends them in different places. This is a matter of no small moment, since the causes which occasion greater or less liability to suffer from a malady may be very different from those which render attacks more or less fatal. Moreover, the laws which govern the outbreak and spread of epidemic maladies might be clearly brought out, and perhaps it may not be too much to anticipate that in the progress of years facts enough might be collected on which to base a prognostication of disease.

The diagrams will now explain themselves. All that is necessary to add is that the small figures below each weekly rainfall signify the number of days on which rain fell in appreciable quantity.

APPENDIX.

No. 4.
On the Quantity, &c. of Venereal in London Institutions, by Mr. W. W. Wagstaffe.

No. 4.—REPORT, by Mr. WILLIAM W. WAGSTAFFE, on the QUANTITY and KINDS of VENEREAL DISEASE under TREATMENT at certain CHARITABLE INSTITUTIONS in LONDON.

Venereal diseases: division of.

IN the following report the term (A) *syphilis* has been applied to (1) the *infecting chancre* and its results, dividing these latter into (2) *constitutional* and (3) *hereditary*. The non-infecting or *soft chancre* (B) as not producing any necessary effects upon the health of the individuals or their children, but being a mere local disease, has been separated from the other venereal affections; and (C) *gonorrhœa* as being a disease distinct from the others, and of more or less special character, has been placed by itself. The term "*Venereal*" has been used to embrace all the above affections, syphilitic and non-syphilitic, which are traceable to contagion. Cases of doubtful character have been excluded from the accompanying tables, but they were not in sufficient number to materially influence the results.

Doubtful cases excluded.

Line of inquiry.

In order to obtain a fair statement of the proportion of cases of venereal disease among the London sick poor, I have, in accordance with instructions, visited one or more of each of the different kinds of institutions which minister to the relief of such persons; general hospitals, special hospitals, dispensaries, and workhouse infirmaries. From the more important of these institutions I have, with the willing permission of the authorities, obtained the returns personally, and am responsible for the diagnosis of the venereal disease in the cases upon which the tables are founded; and in other instances, where I was myself unable to attend, returns have been promptly supplied by the authorities or by trustworthy observers attached to the institution.

In regard to the cases included in this report, it may be stated that only those have been entered as venereal, where the disease for the relief of which the applicant presented himself was due directly or indirectly to some form of venereal affection, and no entry has been made of those who at some previous time in their lives have had one or other kind of such disease. In fact, it would be next to impossible to arrive at the truth if the latter line of inquiry had been taken.

Returns distinguished into departments,

It has been thought better to keep separate the returns for disease among out-patients from those referring to the in-patients of the different institutions, as the class of patients differs materially in the two cases; and also, since the returns which have been previously published on this subject have referred to special departments, to give the full statistics of the different departments into which the out-patient practice is divided.*

and according to sex and age.

It has also been felt desirable, in order to obtain a correct notion of the proportion of each sex affected with venereal disease, to distinguish males, females, and children as far as possible. This, however, was proved to be a difficult matter, for in none of the hospitals or institutions visited is this distinction ordinarily made. In the majority the returns are given under the two headings of "male" and "female," and the children in some cases are entered according to their sex, and in others are numbered with the women. In some institutions there is not even

* The tables printed in this report are summaries of more detailed tables also presented.

this distinction made, and a return is made in mass of the number of patients seen, regardless of their age or sex. The limit of age for "children" for the purpose of the inquiry has been assumed at about 14, or rather puberty, as (although in two instances acquired venereal disease was seen at the respective ages of six and ten, one from rape) it was considered that the age of puberty best marks the time below which the direct acquisition of any venereal affection is improbable.

In making these inquiries I have in the case of out-patients taken the proportion of venereal disease among the whole number of patients presenting themselves during a definite time, one week at the large general hospitals, and two or three days at the dispensaries, and have as carefully as possible avoided counting any patients, whether venereal or non-venereal, a second time, when they attended more than once during the time that institution was under observation. In regard to in-patients, I have followed my instructions in taking the proportion of venereal among them on single days only.

It seems to be the general opinion among the medical officers that the amount of venereal disease (especially among in-patients) is not so large at the present season of the year (August) as during the winter months, and the explanation given is that during the summer, and especially at the present time, men and women do not care to give up the time necessary for treatment in or out of doors, when the plentifulness of harvest and other work gives them the chance of earning good wages. This reason, however, would account for a diminution in the total number of patients, as well as in those affected by the particular class of diseases in question, so that the ratio of the one class of total sickness might be the same as usual, except in one respect, viz., that a much larger proportion of men would probably be drawn off by the summer full work, and as the per-centage of venereal is much higher among them than among women attending as patients, in this manner the total proportion of venereal disease may be somewhat lessened during the summer season among such patients.

Institutions under observation.

Returns have been obtained from among out-patients at the following institutions:—St. Bartholomew's Hospital, St. Thomas's Hospital, St. George's Hospital, for one week each; Royal Free Hospital, for four days; Western General Dispensary, for two days; Finsbury Dispensary, for three days; Farringdon Dispensary, for three days; Surrey Dispensary, for 2 days; Stanhope Street Dispensary, for two days.

And from among in-patients at the following:—St. George's Hospital, London Hospital, Royal Free Hospital, Female Lock Hospital, Male Lock Hospital, Lambeth Workhouse Infirmary, St. Pancras Workhouse Infirmary. The returns from these, as before mentioned, have reference to the patients actually under treatment on one single day in each institution.

OUT-PATIENTS: (1) OF GENERAL HOSPITALS.

Out-patients. General hospitals.— Deficiency of reliable records.

Although not within the immediate objects of this inquiry, it cannot be out of place to give prominent notice here to the deficiency of reliable records of the out-patient practice at all the public medical institutions visited.

For the purpose of clinical instruction such records would be most valuable, and in fact are almost essential to that form of teaching, and in inquiries of the nature of the present one they would also be of the utmost value. For either use, it is of course necessary that their correctness should be guaranteed by proper supervision. At the present

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time none even of the general hospitals which were visited possessed the means of showing, with any approach to accuracy, the proportion of any kind of disease treated among its out patients. A rough entry-book was certainly sometimes kept, but the entries in this were, in the majority of cases, made by junior students, or else by non-medical officials, and in neither case was there any attempt at exactness. There appeared to be no one whose duty it was to overlook these records, or to compile any results from them.

For the following out-patient statistics, all the departments into which that practice is divided have been included; but it has seemed advisable, in recording totals, not to take into consideration the cases of primary accident, *i.e.*, those applying shortly after an accident has happened, as such patients are not of a class fairly comparable with the rest of hospital out-patients. The totals on the Out-patient Tables, relate, therefore, to patients suffering more or less directly from what may be termed "disease," in contradistinction to accident.

Tabulation of returns.

Six tables (I., Ia., Ib., II., IIa., III.) have been prepared from the results obtained from the out-patient practice of general hospitals and dispensaries. Of these, tables I., Ia., Ib., refer to general hospitals only; tables II., IIa. to dispensaries; and table III. combines the results obtained from the inspection of the total out-patients (9,363), seen at both classes of institutions. The different departments of out-patient practice at general hospitals, which have, for reasons before stated, been kept distinct, are as follows:—1. Surgical out-patients, under the care of the assistant-surgeon; 2, surgical casualties; 3, ophthalmic patients; 4, medical out-patients under the care of the assistant physician; 5, medical casualties; 6, special department for diseases of women and children; and 7, department for skin diseases. The sexes have been distinguished, and children separated from women, where such a course has been found possible.

Except where otherwise stated, the returns have been obtained by myself.

Sources from whence returns obtained.

The following are the points which it appears necessary to note concerning the specialities of the out-patient practice at each hospital visited; and here I desire to record the names of the gentlemen to whom I am indebted for assistance in each department.

ST. BARTHOLOMEW'S.—Five departments formed the subject of inquiry at this hospital, and I have to acknowledge with pleasure the readiness with which all the officers of the institution assisted me by giving information, and by putting their patients at my disposal for examination:—1, the surgical out-patients' department, under the care of the assistant-surgeon, and including the ophthalmic and aural practice; 2, the surgical casualty department. The patients here were very numerous, and were carefully tabulated by the house surgeon; 3, the medical out-patients were noted by the assistant physicians in attendance (Drs. Southey, Church, and Gee); 4, the medical casualties; and 5, the department for diseases of women and children included no cases of venereal disease, as such are at once transferred to the surgical authorities.

ST. THOMAS'S HOSPITAL.—Seven departments are recognized here among the out-patients. 1. The surgical out-patients under the care of the assistant-surgeons. 2. The surgical casualties under the care of the house surgeons and dressers in which the returns were rendered by the former. 3. The ophthalmic out-patients. 4. The medical out-patients, for the accounts of which I am indebted to Dr. Clapton, the assistant physician. 5. The medical casualties seen by the resident medical officer or his assistant. 6. The department for skin diseases, the returns from which are furnished by Dr. Bristowe. 7. The obstetric special children's department under the care of Dr. Barnes and Dr. Gervis, who supplied the returns for this department.

APPENDIX.

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On the Quantity, &c. of Venereal in London Institutions, by Mr. W. W. Wagstaffe.

TABLE I.—OUT-PATIENTS of General Hospitals.—TOTAL NUMBERS.*

Departments.	Surgical Out-patients.			Surgical Casualty.			Ophthalmic.			Medical Out-patient.			Medical Casualty.			Special Women and Children.		Skin.			Total according to Sex.			Grand Totals.
	M.	F.	CH.	M.	F.	CH.	M.	F.	CH.	M.	F.	CH.	M.	F.	CH.	F.	CH.	M.	F.	CH.	M.	F.	CH.	
No. of Out-patients	285	316	74	314	218†		—	—	—	127	268†		670	1,219†		120†		—	—	—	1,396	2,141	74	3,611
ST. BARTHOLOMEW'S:																								
Gonorrhœa, &c.	29	16	0	73	20					0	0		0	0		0					102	36	0	138
Soft chancre	13	7	0	9	0					0	0		0	0		0					22	7	0	29
Syphilis acquired	66	27	0	21	4					8	6		0	0		0					87	31	0	118
Do. hereditary	0	0	8	0	1					0	0		0	0		0					0	0	9	9
Venereal	108	50	8	103	25		—	—	—	8	6		0	0		0		—	—	—	211	74	9	294
No. of out-patients	160	195	139	188	261	177	28	74†		168	171		27	77	24	278	67	20	24	23	591	1,080	430	2,101
ST. THOMAS'S:																								
Gonorrhœa, &c.	31	2	0	23	3	0	1	0		0	0		0	0	0	0	0	0	0	0	55	5	0	60
Soft chancre	4	1	0	3	2	0	0	0		0	0		0	0	0	1	0	0	0	0	7	4	0	11
Syphilis acquired	25	22	0	3	2	0	4	5		2	1		0	0	0	3	0	2	0	0	36	33	0	69
Do. hereditary	0	0	2	0	0	0	1	0		0	1		0	0	0	3	2	0	0	0	1	4	4	9
Venereal	61	25	2	29	7	0	6	5		2	2		0	0	0	7	2	2	0	0	99	46	4	149
No. of out-patients *	142	187	80	0	0	0	17	39	21	147	280	71	0	0	0	31†		0	0	0	306	537	172	1,015
ST. GEORGE'S:																								
Gonorrhœa, &c.	18	2	0	—	—	—	0	0	0	1	0	0				0					19	2	0	21
Soft chancre	6	0	0	—	—	—	0	0	0	0	0	0				0					6	0	0	6
Syphilis acquired	15	15	0	—	—	—	0	1	0	1	2	0				0					26	18	0	44
Do. hereditary	0	0	2	—	—	—	0	0	1		0	0				0					0	0	3	3
Venereal	39	17	2	—	—	—	0	1	1	12	2	0	—	—	—	0		—	—	—	51	20	3	74
No. of out-patients	341	160	48	55	65	19	0	0	0	328	439	35	0	0	0	0	0	0	0	0	724	664	102	1,490
ROYAL FREE:																								
Gonorrhœa, &c.	99	8	0	0	0	0				4	2	0									103	10	0	113
Soft chancre	23	2	0	0	0	0				0	0	0									23	2	0	25
Syphilis acquired	43	27	0	0	0	0				25	19	0									68	46	0	114
Do. hereditary	0	0	3	0	0	0				0	0	1									0	0	4	4
Venereal	165	37	3	0	0	0	—	—	—	29	21	1	—	—	—	—	—	—	—	—	194	58	4	256

* The time of observation was a week in the case of St. Bartholomew's, St. Thomas's, and St. George's respectively, and four days at the Royal Free.

† In these cases women and children were not taken separately.

NOTE.—Where lines are drawn obliquely across the spaces the special department was not represented.

TABLE I a.

PER-CENTAGE SUMMARY of VENEREAL DISEASES occurring among OUT-PATIENTS at General Hospitals.

Departments.	Surgical Out-patients.			Total.	Surgical Casualties.			Total.	Ophthalmic.			Total.	Medical Out-patients.			Total.	Medical Casualties.			Total.	Special Women and Children.		Total.	Skin.			Total.	Total according to Sex.			Total.
	M.	F.	CH.		M.	F.	CH.		M.	F.	CH.		M.	F.	CH.		M.	F.	CH.		F.	CH.		M.	F.	CH.		M.	F.	CH.	
St. Bartholomew's	37·89	15·82	10·81	23·11	32·80	11·00	0	24·06	—	—	—	—	0·39	2·23	0	3·54	0	0	0	0	0	0	0	—	—	—	—	15·11	3·45	10·81	8·14
St. Thomas's -	37·50	12·82	1·43	17·61	15·42	2·68	0	5·78	17·85	6·75	(·98)	10·78	1·19	·58	0	1·18	0	0	0	0	1·43	2·98	2·60	10·0	0	0	2·9	16·57	3·88	·9	7·09
St. George's -	27·45	9·08	2·50	14·18	0	0	0	0	0	2·56	4·76	2·59	8·16	·71	0	2·81	—	—	—	—	0	0	0	—	—	—	—	16·29	3·88	1·17	7·22
Royal Free -	48·38	23·12	6·24	37·34	0	0	0	0	—	—	—	—	8·83	4·78	2·85	6·36	—	—	—	—	—	—	—	—	—	—	—	26·78	8·72	3·92	17·17

TABLE I b.

Particular forms of VENEREAL, per cent. of total PATIENTS irrespective of Age and Sex, under Treatment as OUT-PATIENTS at General Hospitals.

—	St. Bartholomew's.	St. Thomas's.	St. George's.	Royal Free.
Gonorrhœa or complications -	3·82	2·85	2·05	7·58
Soft chancre - - -	·80	·52	·58	1·67
Syphilis acquired - - } Do. hereditary - - }	3·51	3·71	4·59	7·92
Venereal in any form -	8·14	7·09	7·22	17·17

ST. GEORGE'S HOSPITAL.—At this hospital five departments are recognized among the out-patients. 1. The surgical out-patients under the care of the assistant-surgeons. 2. The surgical casualties comprise only accidents and emergent cases, and are therefore not taken into consideration in the statistics. 3. For the return of medical cases I am indebted to the kindness of the assistant physicians (Drs. Dickinson and J. W. Ogle). 4. The women's special department under the care of Dr. J. Clarke, showed no cases of venereal. 5. The ophthalmic out-patients.

The proportion of venereal is rather less among the assistant surgeons' surgical out-patients than at either of the other two general hospitals, (14 per cent. against 17 and 23 per cent.,) and this is more marked among the males of this department, for it will be seen that at St. George's 27 per cent. of males are affected against 37 per cent. among the assistant-surgeons' out-patients at St. Bartholomew's and St. Thomas's.

ROYAL FREE HOSPITAL.—The surgical out-patient here comprised an unusually large number of venereal cases in comparison with other general hospitals. At this institution there seems to be a tendency to make a speciality of this class of diseases, owing partly to the original associations of the place,* and partly to the fact that the name and reputation of the hospital lead many to suppose no questions are asked and no trouble is necessary in order to obtain relief as an out-patient.

The per-centage of venereal among the surgical males here rises to nearly 50, or one out of every two seen, and for all sexes and ages in this department to 37·34, or more than one out of three; while the total per-centage for all sexes and departments among the out-patients reaches to over 17 per cent.

The notes of the cases occurring on the medical side were made by Dr. Keagey, late of St. Thomas's Hospital, who was present during the four days this institution was under observation and fully satisfied himself of the correctness of the details collected.

Among the surgical casualties no cases of venereal occurred.

OUT-PATIENTS (2) OF DISPENSARIES.

Dispensaries.

Returns were supplied from the following:—1. Western General Dispensary, Marylebone Road, by Mr. John Waller, the Resident Medical Officer, 2. Finsbury Dispensary, Woodbridge Street, by Mr. Lewis J. May, Resident Medical Officer. 3. Farringdon Dispensary, by the Medical Officers. 4. Surrey Dispensary, by Mr. F. W. Smith, House Surgeon. 5. The Public Dispensary, Stanhope Street, by Mr. H. Morris, M.B., House Surgeon.

Why proportion of venereal disease among these is small.

A much smaller proportion of venereal disease is to be noticed in these returns than in those from the general hospitals. The explanation, however, of this is apparent. In all the dispensaries, the production of a Governor's letter is necessary before a patient can be seen by the surgeon or physician, and a large number, if not the majority of the patients are connected by ties of dependence with the donors of the letter. Persons suffering from contracted venereal disease will hesitate to seek for a letter under these circumstances with the almost absolute certainty of being asked by the governor the nature of their malady, especially when hospitals are at hand offering treatment without fear of this disease becoming known elsewhere.

This reason bears upon all dispensaries, and in addition there is among most of them a rule, expressed or traditional, that primary venereal affections are not fit objects for the charity of the governors.

Hereditary syphilis.

The proportion of cases of hereditary syphilis at dispensaries may probably be looked upon as more correct for sick children generally,

* The hospital was founded ostensibly for the relief of the most destitute poor, who could not get letters of recommendation to the other hospitals; and of this class of persons prostitutes formed a notable proportion.

TABLE II.

OUT-PATIENTS of DISPENSARIES.

TOTAL NUMBERS.

—	Western General Dispensary. (2 Days.)				Finsbury Dispensary. (3 days.)				Farringdon Dispensary. (3 days.)				Surrey Dispensary. (2 days.)				Stanhope Street Dispensary. (2 days.)				Totals according to Sex.			
	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.
Number of Patients seen - -	98	164	78	340	25	127	69	221	51	113	28	192	69	227	24	320	15	41	8	64	258	672	207	1,137
Gonorrhœa or Complications -	2	0	0	2	0	0	0	0	6	1	0	7	1	0	0	1	3	0	0	3	12	1	0	13
Soft chancre - - - -	1	2	0	3	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	2	3	0	5
Syphilis, acquired - - -	2	3	0	5	0	2	0	2	3	3	0	6	0	1	0	1	0	1	0	1	5	10	0	15
Ditto, hereditary - - -	0	0	7	7	0	0	2	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	10	10
Venereal of all forms - -	5	5	7	17	0	2	2	4	10	5	0	15	1	1	1	3	3	1	0	4	19	14	10	43

TABLE II a.

PER-CENTAGES.

Proportion per cent. of																								
Gonorrhœa or Complications -	2·04	0	0	·59	0	0	0	0	11·76	·88	0	3·64	1·44	0	0	·31	20·0	0	0	4·70	4·65	·14	0	1·14
Soft chancre - - - -	1·02	1·22	0	·88	0	0	0	0	1·96	·88	0	1·04	0	0	0	0	0	0	0	0	0·77	·44	0	·44
Syphilis, acquired - - -	2·04	1·82	0	1·47	0	1·57	0	·91	5·88	2·65	0	3·12	0	·44	0	·31	0	2·43	0	1·56	1·93	1·48	0	1·32
Ditto, hereditary - - -	0	0	8·97	2·06	0	0	2·89	·91	0	0	0	0	0	0	4·16	·31	0	0	0	0	0	0	4·83	·88
Venereal of all kinds - -	5·10	3·04	8·97	5·00	0	1·57	2·89	1·82	19·60	4·41	0	7·80	1·44	·44	4·16	·94	20·0	2·43	0	6·26	7·36	2·08	4·83	3·78

here than at a large general hospital, where a comparatively larger number of acute cases is received, and where it is much more difficult, without the employment of special means, to separate accurately the number of children from the rest of the patients seen. It will be observed in the return that 4·83 per cent. of the sick children applied with disease traceable to syphilis in their parents.

SUMMARY OF OBSERVATIONS ON OUT-PATIENTS.

At hospitals the proportion of venereal disease is very different in different departments of out-patients.

From the preceding tables it is evident that in the three general hospitals (St. Bartholomew's, St. Thomas's, and St. George's), which represent most fairly the general hospitals of the Metropolis, a great difference exists in the several departments in regard of the prevalence of venereal disease. By far the greater proportion appears in the surgical practice (including surgical out-patients, surgical casualties, and ophthalmic out-patients) and a statement to the public of returns derived from such surgical out-patients alone would considerably exaggerate the prevalence of venereal generally among the sick poor of London. At St. Bartholomew's for instance, the proportion of venereal among surgical out-patients is over 23 per cent., whereas among the out-patients generally, excluding primary accidents it is just over 8 per cent. A similar difference is also observable at the Royal Free Hospital. The returns from the dispensaries do not satisfactorily separate the medical from the surgical practice, but the same proportionate difference would probably not be found, as there is not usually the same care in distinguishing between the two classes of cases.

Close agreement in the returns from the general hospitals.

Although much larger numbers of patients always attend on the early days of the week, I do not find that the proportion of venereal cases among them is appreciably different.

The three large general hospitals agree very closely as to their results as the following per-centage figures will show.

Disease.	St. Bartholomews.	St. George's.	St. Thomas's.	Royal Free.
Gonorhœa - -	3·82	2·05	2·85	7·58
Soft chancre - -	·80	·58	·52	1·67
Syphilis - - -	3·51	4·59	3·71	7·92
Venereal generally -	8·14	7·22	7·09	17·17

Compared with these the Royal Free Hospital presents a much larger per-centage, and the increase seems nearly equal in the three classes into which venereal disease is divided.

The return from dispensaries gives a total of gonorrhoea 1·14; soft chancre, ·43; syphilis, 2·19; giving a total per-centage of venereal, 3·78.

The total results of the foregoing returns from the out-patient departments of different institutions collectively are embodied in Table III., by which it will be seen that of 9,363 out-patients in all departments of all the charitable institutions visited, 8·71 per cent. were affected with venereal disease of some kind, and of these 3·68 were gonorrhœa, ·81 were soft chancre, 4·21 were syphilis.

TABLE III.

TOTAL VENEREAL among OUT-PATIENTS of HOSPITALS and DISPENSARIES reported upon.

—	ACTUAL NUMBERS.				—	PER-CENTAGE NUMBERS.			
	Males.	Females.	Children.	Total.		Males.	Females.	Children.	All Ages and Sexes.
Number of Patients - -	3,282	5,097	984	9,363	Proportion per cent. of	100	100	100	100
Gonorrhœa or Complications	291	54	0	345	Gonorrhœa or Complications	8·86	1·06	0	3·68
Soft chancre - -	60	16	0	76	Soft chancre - -	1·82	·31	0	·81
Syphilis, acquired - -	222	139	0	361	Syphilis, acquired - -	6·76	2·73	0	3·85
Ditto, hereditary -	0	0	34	34	Ditto, hereditary -	0	0	3·45	·36
Venereal of all kinds -	573	209	34	816	Venereal of all kinds -	17·44	4·10	3·45	8·71

IN-PATIENTS OF GENERAL HOSPITALS AND WORKHOUSES.

In-patients.—Manner in which returns were taken.

The returns of in-patients affected with venereal diseases in different institutions are not sufficiently comprehensive to afford a basis for any general deductions. I have therefore simply given the results in the Tables IV. and IV a.—Table IV. showing the total numbers, and IV a. the proportions per cent., and have not attempted to combine them. A more extended inquiry would be necessary before a fair judgment of the proportion of venereal disease among the in-patients generally of London hospitals could be formed. The plan has been adopted of taking the actual number of patients in hospital on a particular day, noting the number of venereal cases found among them; so that the returns represent the proportion of venereal in hospital on a specified day.

Sources from whence obtained.

For the return from St. George's Hospital I am indebted to the surgical registrar, Mr. Wm. Leigh, and may state it is his impression that the proportion at the present time is rather below their average of such cases.

At the London Hospital the returns were made by the registrars (Mr. Tay and Dr. Woodman), and they too are of opinion that their present number of venereal cases is smaller than usual. St. Bartholomew's and Guy's Hospitals have furnished no returns. At the Royal Free Hospital, there is an even greater proportion of venereal cases among in-patients, as compared with other general hospitals than was noticed among the out-patients, but this is not surprising when of the only two female wards in the hospital one is exclusively devoted to venereal affections.

From the two workhouses of Lambeth and St. Pancras, I have with the permission of the authorities personally investigated the venereal cases among the inmates of the infirmaries, and the great difference in the results obtained requires some explanation. Lambeth shows a per-centage of 2·53 venereal cases in the infirmary, while in St. Pancras it amounts to 10·6. In the Lambeth Infirmary, however, the proportion of venereal to total diseases is due to the fact that a much larger proportion of cases of senile debility are lodged there than at St. Pancras; in fact, the excess in the actual number of inmates in Lambeth Workhouse Infirmary over those in St. Pancras is completely made up by patients suffering from old age rather than from any actual disease. In the former, the number of patients in the infirmary is 315 out of a total of 944 in the workhouse, while at St. Pancras (the old people being lodged elsewhere) only 132 out of 1,645 are infirmary patients. If the proportion of venereal cases to the whole number of inmates be taken, the results for the two workhouses would be found almost identical, being 0·84 per cent. for Lambeth, and 0·85 per cent. for St. Pancras.

PATIENTS OF SPECIAL LOCK HOSPITALS.

Special hospitals.

In order to obtain further materials for determining the quality of prevalent venereal disease, I have applied for and obtained returns from the Female Lock Hospital and from the Male Lock Hospital through the kindness of their respective medical officers, Mr. F. J. Marshall and Mr. C. H. Lister.

Mr. Berkeley Hill has also forwarded me a report of the out-patients under his care, from the commencement of the present year to June 30th.

From these it would appear that the number of cases of gonorrhœa among in-patients at the special hospitals reported upon was proportionally much greater than any other forms of venereal. The out-patients have not been classed in Mr. Hill's returns in the same manner, but simply into syphilitic and non-syphilitic, and show a proportion 41·5 per cent. of the former against 58·5 per cent. of the latter. Tables setting out in detail the facts about the nature of the venereal diseases treated at these hospitals accompany this report.

TABLE IV.

IN-PATIENTS of General HOSPITALS and WORKHOUSES.

TOTAL NUMBERS.*

	St. George's Hospital.				London Hospital.				Royal Free Hospital.				Lambeth Workhouse.				St. Pancras Workhouse.			
	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.	M.	F.	CH.	Total.
No. of Patients under Treatment - - -	160	148	0†	308	293	154	30	477	44	37	0	81	116	178	21	315‡	50	63	19	132§
Gonorrhœa and Complication - - -	1	1	0	2	1	1	0	2	0	6	0	6	0	0	0	0	1	2	0	3
Soft chancre - - - - -	0	1	0	1	0	0	0	0	0	3	0	3	0	0	0	0	3	4	0	7
Syphilis, acquired - - - - -	10	13	0	23	8	9	0	17	3	11	0	14	2	6	0	8	2	2	0	4
Ditto, hereditary - - - -	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Venereal of all kinds - - -	11	15	0	26	9	10	4	23	3	20	0	23	2	6	0	8	6	8	0	14

TABLE IV a.

PER-CENTAGES.

Proportion per cent. of Gonorrhœa and Complications - - -	·62	·67	0	·65	·34	·65	0	·42	0	16·21	0	7·40	0	0	0	0	2·0	3·17	0	2·27
Soft chancre - - - - -	0	·67	0	·32	0	0	0	0	0	8·10	0	3·70	0	0	0	0	6·0	6·34	0	5·30
Syphilis, acquired - - - - -	6·25	8·78	0	7·46	2·72	5·84	0	3·56	6·81	29·73	0	17·28	1·72	3·36	0	2·53	4·0	3·17	0	3·03
Ditto, hereditary - - - -	0	0	0	0	0	0	13·33	·84	0	0	0	0	0	0	0	0	0	0	0	0
Venereal of all kinds - - -	6·87	19·12	0	8·44	3·06	6·49	13·33	4·82	6·81	54·04	0	28·38	1·72	3·36	0	2·53	12·0	12·68	0	10 60

* NOTE.—These numbers represent the results of observations made on a single day in each institution.
† In the return from St. George's Hospital the children are not separated from females.
‡ NOTE.—The total number of inmates of Lambeth Workhouse, including Infirmary and all departments, was 944, and the proportion of venereal sick was therefore 0·84 per cent.
§ NOTE.—The total number of inmates of St. Pancras Workhouse, including Infirmary and all departments was 1,645, and the proportion of venereal sick was therefore 0·85 per cent.

TABLE V.

IN-PATIENTS of LOCK HOSPITALS.

	Female Lock.			Male Lock.			Total.	Proportion per cent.
	M.	F.	CH.	M.	F.	CH.		
Total number of patients -	0	123	0	15	0	0	138	0
Gonorrhœa or complications.	0	61	0	2	0	0	63	45·65
Soft chancre - -	0	28	0	7	0	0	35	25·36
Syphilis, acquired -	0	34	0	6	0	0	40	28·98
Ditto, hereditary -	0	0	0	0	0	0	0	0

OUT-PATIENTS OF LOCK HOSPITALS.

	Under Treatment during six months at the Female Lock Hospital.	
Number of patients -	378	Proportion per cent.
Non-syphilitic - -	157	41·53
Syphilitic - -	221	58·47

GENERAL OBSERVATIONS.

The foregoing returns have reference to the amount and kinds of venereal disease observed during a certain time at various charitable institutions in London; and it may not be amiss in conclusion to give an approximate of these proportions among the total sick poor of the metropolis.

Definition of the term "sick poor."

Confining the term "sick poor" to such as receive medical relief gratuitously at public institutions, and at the hands of the poor law administrators, it will be necessary, in order to obtain an idea of their numbers, to take them as follows: (A) those relieved at general hospitals, (B) those relieved at dispensaries and special hospitals, and (C) those receiving parochial medical relief.

Estimation of total numbers of sick poor of the metropolis.

The calculation of the total numbers relieved by these different means can only be an approach to the truth, for in many instances no returns are published or kept; in others there is no attempt whatever at accuracy; while at many of the charitable institutions there is a tendency to greatly overstate the amount of real work done. From the actual returns where obtainable, and from other sources where no returns are made, it seems that the following will represent the total number of sick poor relieved during the year:

(A) At general hospitals, as shown by their returns	554,450
(B) At special hospitals and dispensaries, as shown by their returns - - - -	800,000
(C) By parish medical officers (calculated) -	180,000
Total - - - -	1,534,450

It appears further that those hospitals and dispensaries which have been the subject of this report minister to the relief of a very large proportion of the sick poor contained in classes (A) and (B)—as much,

APPENDIX.

No. 4. *On the Quantity, &c. of Venereal in London Institutions, by Mr. W. W. Wagstaffe.*

in fact, as 25 per cent., or one-fourth. But it will evidently be incorrect to give the proportion of venereal diseases which occur among these patients (A) and (B) as the proportion of venereal diseases among the total sick poor of the metropolis. It will be necessary to add 25 per cent. of the parochial sick (C) before fair deductions can be made. It would be a matter of considerable difficulty however to give the return of this class of cases (C) with accuracy; it would require greater time and labour than the results to be obtained would counterbalance. But I have computed it, I think not unfairly, by obtaining a return from each of the medical officers of one of the largest unions (Lambeth). From these it would seem that 0·33 per cent. of the population, or one in 300, receive relief from the parochial medical officers in an average week. Taking the population to be about 3,000,000, it will follow that about 9,900 are weekly under the hands of the parish medical officer, and one-fourth of this number, or 2,475, must be added to the corresponding fourth of hospital and dispensary patients included in this report. Venereal in these parish out-patients is not treated by the parish doctor, but is accounted for in various hospital returns.

A week's return of one-fourth of the sick poor of London, showing the proportion of venereal cases among them.

The following will therefore represent a weekly return of the number and proportion of venereal cases during about a week's observation of in-patients, out-patients, and parish cases among about one-fourth of the whole population of the metropolis :—

Class of Patients.	Total Number reported on.	Number of Venereal Cases.	Proportion of Venereal Cases per cent.
In-patients of hospitals, dispensaries, and workhouse infirmaries - -	1,313	94	7·16
Out-patients of hospitals and dispensaries	9,363	816	8·71
Parochial out-patients - - -	2,475	0	0
Totals - - -	13,151	910	6·92

So that 6·92 will probably represent the per-centage of the sick poor population affected with some form of venereal disease, syphilitic or non-syphilitic.

Proportion of syphilitic and non-syphilitic cases arranged according to sex.

If we inquire a little further, and distinguish the non-syphilitic from the syphilitic forms of disease, and separate men, women, and children into different groups, we may obtain the following results :—

——	Total.	Males.	Females.	Children.
Total number of patients reported on -	13,151	4,935	6,647	1,569
Of which there were suffering from				
(*a*) Non-syphilitic forms of venereal disease.	445	357	88	0
(*b*) Syphilitic - - - -	465	247	180	38
Totals - - -	910	604	268	38
Or expressed in per-centages :				
(*a*) Non-syphilitic - - -	3·38	7·23	1·32	0
(*b*) Syphilitic - - -	3·53	5·00	2·71	2·42
Total - - -	6·92	12·23	4·03	2·42

If this report be considered extensive enough (and it comprises about a week's observation of presumably one quarter of the sick poor of London) to warrant general deductions being made, it may be inferred that among the million and a half of poor population of the metropolis who receive medical relief for disease at hospitals, dispensaries, workhouses, and at the hands of the parochial medical officers during the year, nearly 7 per cent., or about 1 in 14, are affected with venereal disease of some kind. These numbers, it must be remembered, do not include midwifery cases.

The amount of true syphilis is slightly in excess of the non-infecting forms of venereal disease, but the contrary holds good when men are considered apart from women and children; for among this sex the percentage of non-syphilitic stands at 7·23 against 5·00 per cent. of syphilis. By far the larger proportion of venereal disease is to be noted among the males, the returns showing three times as much among them as among females. The proportion of hereditary syphilis among children cannot, I am afraid, be satisfactorily deduced from these tables, as no cases have been reported in the parochial returns. In order, however, to obtain some data for a rough estimate of the quantity of hereditary syphilis among the sick children of the class that would frequent hospitals, the published statistical returns of the Great Ormond Street Hospital have been examined, and it appears that of 118,590 children treated there as in and out patients during the last ten years, 1,786, or a proportion of nearly 1½ per cent., are recorded to have been syphilitic.

No. 5.—FURTHER REPORT by Dr. SANDERSON on the INOCULABILITY and DEVELOPMENT of TUBERCLE.

No. 5.
On the Inoculability, &c. of Tubercle, by Dr. Sanderson.

IN my last report I expressed the opinion, in terms as definite as my observations seemed to justify, that the disease produced by tuberculous inoculation might be regarded as an overgrowth in the affected parts of those structural elements which they have in common with the pulp contained in the alveoli of the lymphatic glands. I had also found that the structural alterations in which the disease manifested itself were remarkably constant in their character and development—consisting of (1.) Induration and suppuration of the subcutaneous connective tissue at the point of insertion, attended with the formation of secondary nodules of induration of the same tissue in the immediate neighbourhood. (2.) Enlargement, induration, and caseous degeneration of the lymphatic glands in relation with the seat of primary infection. (3.) Appearance of nodules in the lungs, having to the naked eye the translucent aspect of grey tubercle, though differing therefrom in structure. (4.) Enlargement of the liver, consequent on interstitial growth of new material between the lobules. (5.) Hypertrophy of the spleen. (6.) Formation in various parts of the peritonæal surface of nodules, consisting of elements anatomically identical with those naturally to be found in the affected parts.

Summary of conclusions contained in last report.

As regards the conditions of infection, I had concluded from experiments that in rodent animals the tuberculous process may originate not merely by the inoculation of tubercle, but by any irritation of the requisite intensity applied to the subcutaneous tissue, and that any external injury, provided that the animal survives its immediate effects, is capable

of becoming the first link in a chain of pathological changes which cannot be distinguished from those produced by the insertion of tuberculous material. In correspondence with this inference, I had found that in almost every animal inoculated, suppuration had occurred at the point of insertion, a fact which seemed to indicate that, however specific might be the characters of the subsequent stages of the process, the characteristic phenomenon of common inflammation attended its origin. Had abscesses been found at the seat of inoculation in every case, I should have been compelled to believe that the formation of pus was essential. But it was not so, for in some of the animals there were no abscesses.

The facts from which I had concluded that tuberculosis may originate traumatically, although very limited in number, were of so positive a nature that I ventured to state that the results of tuberculous inoculation could no longer be regarded as necessarily dependent on any property or action possessed by the inoculated material in virtue of its having been taken from a tuberculous individual.* The truth of this inference has now been completely established by the experiments of two of the most competent observers, Dr. Wilson Fox, Professor of Clinical Medicine in University College,† and Dr. Cohnheim of Berlin. The following paragraph contains a summary of their results, which are the more valuable as they were arrived at altogether independently and without knowledge either of each other's inquiries or of mine.

Observations of Dr. Wilson Fox and Dr. Cohnheim as to the conditions of tuberculous infection.

From the tabular summary of Dr. Fox's experiments (117 in number), it appears that of 70 animals inoculated with various products derived from bodies of non-tuberculous patients, about half (34) became tuberculous. In addition, five animals were inoculated with putrid but originally healthy muscle, and four of them became in like manner tuberculous, as was found when they were killed at various periods from 84 to 122 days after inoculation. Of seven animals in which setons or other mechanical irritants were introduced under the skin, two became tuberculous.‡ This research, no less remarkable for the accuracy and completeness of the anatomical details than for the conclusiveness of the experiments, was followed only the other day by another in Berlin, which although of similar nature appears by internal evidence to have been conducted in entire ignorance that several of the questions investigated had already been completely settled in England. Drs. Cohnheim and Fränkel, for the purpose of obtaining an answer to the question, "Does artificial tubercle owe its origin to a specific virus?"§ introduced into the peritonæal cavities of guinea pigs portions of various tumours (carcinoma, sarcoma, condyloma, &c.), as well as of healthy but

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* With reference to the traumatic origin of tuberculosis in the guinea-pig, another possibility claims consideration, namely, that of the influence of the air and of the organisms which it contains. It has not yet been proved that injuries, which are of such a nature that air is completely excluded from contact with the injured part, are capable of originating a tuberculous process. The following experimental results seem, indeed, to suggest that they may not be so. Setons steeped in carbolic acid were inserted in 10 guinea-pigs on the 24th of September 1868, each animal receiving two. At the same time extensive fractures of both scapulæ were produced in five others, care being taken not to injure the integument. No tuberculosis or other disease of internal organs has resulted in either case.

† "On the Artificial Production of Tubercle in the Lower Animals."—London: McMillan & Co., 1868.

‡ It is of importance to note that all these experiments were completed before the appearance of my last report.

§ Cohnheim and Fränkel. Untersuchungen über die Ueberträgbarkeit der Tuberculose auf Thiere. Virch. Archiv. Bd. xlv. 1868, p. 216.

partly decomposed tissue. Subsequently they employed in the same way a variety of insoluble inert substances, such as blotting paper, charpie, gutta percha, caoutchouc, vulcanite, &c. In those animals that survived the immediate effects of the injury, emaciation supervened sooner or later, and the animals eventually died with tuberculosis of the peritonæum, liver, spleen, lungs, and other organs, the morbid appearances corresponding in every respect with those described in my last report.

Perfect identity of artificial tuberculosis with miliary tuberculosis in man.

As regards the bearing of these facts on the general question of the nature and origin of tuberculosis, I concluded from my own observations that there is no structural distinction between the artificial disease and human tubercle, so long as the term is confined, as all accurate writers are now accustomed to confine it, to miliary tuberculosis; but I considered it necessary to maintain a reserve as to its relation with the many pathological processes which are spoken of as tuberculosis in the common language of practical medicine and surgery. In going so far the two distinguished pathologists already quoted have fully agreed with me. Dr. Fox says: "I must confess that sceptical as everyone must "naturally at first feel on this subject, the cumulative force of the "evidence in favour of the tubercular nature of these growths appears "to me irresistible. We are either dealing with tubercle, or we have "before us a new and hitherto unknown constitutional disease of the "rodentia, consisting of growths which, in their naked eye appearances "and histological characters, correspond with all the essential features "of tubercle in man; which occur not only in the organs which are the "chosen seats of tubercle in man, but also in the same parts of those "organs; which have the same vital characters, and the same early degene-"rative cheesy changes, not suppuration nor acute softening, and with "no marked characters sufficient to distinguish them from tubercle."* Cohnheim says, "All the marks by which tubercle is characterized, as "such, are present; the agreement of the product of inoculation with "human miliary tubercle could not be more complete than it is, whether "regard be had to its extended distribution, and to the great variety of "organs affected, (peritonæum, pleura, lungs, liver, spleen, lymphatic "glands, and even the choroid,) or to its macroscopical and micro-"scopical characters."

In the work done during the past year my first object has been to amplify and elaborate the pathological results comprehended in my former report, to confirm what was left imperfectly established, to elucidate what was obscure, and to endeavour to bring the inquiry into more direct bearing on the most important of all etiological questions, that of the origin and development of tuberculosis in man.

Structural characters of tubercle.

It has been already said that in the liver, lungs, and some other organs, the material which constitutes the new growth presents uniform structural characters which, although they are met with in many other parts of the body, are most distinct in the alveolar pulp of lymphatic glands. To imply this resemblance I proposed to designate these characters by the word *adenoid*. My further inquiries lead me to believe, in the first place, that these characters belong much more generally to tuberculous growths than I had at first supposed; and secondly, that those normal tissues which possess them are much more liable to become the seat of the tuberculous process than others. To illustrate these points it will be necessary not only to refer to my own observations, but to render available all the discoveries which have been made during the last six or seven years which bear upon the question.

* Fox, loc. cit. p. 20. Cohnheim, l. c. p. 219.

Characters and Anatomical Distribution of natural Adenoid Tissue.

The existence of the tissue in question has been for some years recognized by all minute anatomists. Kölliker first described it under the term "*cytogene Bindesubstanz.*" For the more complete elucidation of its structure and significance, science is indebted to Professor His of Basle, who first applied to it the term "*adenoide Substanz.*"* Other histologists speak of it as *netzförmige* or *reticuläre Bindesubstanz, Zellengerüst,* &c. Kölliker defines the tissue generally as "a reticulum "of stiff, pale fibres, comprising lymph corpuscles in its meshes, "originating by the combination of branched cells, consisting neither of "gelatigenous nor of elastic substance, but of an albuminous compound, "soluble in caustic alkali, but not in boiling water."

Reticular cytogenic tissue is to be found in the lymphatic glands, in the spleen, in the neighbourhood of the ducts of the liver and of the bronchi in the serous and mucous membranes, and in the medulla of bone. I proceed to refer to its character and distribution in most of these organs.

Structure of the adenoid pulp of the lymphatic glands.

The structure of the lymphatic glands has been understood by anatomists only for a short period.† A few years ago it was supposed that a lymph-gland consisted essentially in a network of finely-divided lymphatic vessels, compacted into a dense mass by cellular tissue, and abundantly supplied with blood vessels. It was imagined that the afferent lymphatics divided into minute branches which, after forming an intricate plexus in its interior, combined again to become the efferent vessels. Somewhat more recently it was recognized that the afferent lymphatic channels were not continuous with the efferent as such, but that they lost themselves in certain holes filled with cells, since called alveoli, from which the efferent vessels took their origin. The first step towards a more exact knowledge of the subject was taken in 1852–53, when Brücke ‡ and Donders § showed that these holes were not mere dilatations of lymphatics, but that they contained structures of considerable complication; that in addition to the lymph corpuscles, which were before thought to be the sole occupants of the alveoli, each alveolar cavity is permeated by a network of transparent fibres. They further showed that this network is so arranged as to form a flask-shaped body (since called by His an ampulla), the contour of which corresponds to that of the cavity (alveolus) which it occupies, being, as it were, suspended in it by delicate strings of transparent connective material which stretch across the space between its outer surface and the inner surface of the alveolus. Thus the structure of the medullary substance of a lymphatic gland (in the part in which the alveoli are) may be described as follows:—It consists of a number of flask-shaped cavities, communicating with each other by their necks, enclosed in a meshwork consisting of beams and septa, all of which spring from the general capsular investment of the gland, and tend towards the hilus. These have for their

* Kölliker, Handbuch der Gewebelehre des Menschen, pp. 58 and 64. Prof. W. His, Beiträge zur Kenntn. der zum Lymphsystem gehörigen Drüsen, p. 65.

† If it were necessary to seek for a reason for introducing these details into this Report, I should find it in the fact that even in the later editions of English text books of physiology the structure of the lymphatic glands is still described as it was known to anatomists of 20 years ago.

‡ Brücke, Sitzungsberichte der Akad. der Wissenschaften zu Wien. March 1853, p. 429.

§ Donders, Physiol. des Menschen, Band I. (Theile's translation), p. 318.

exclusive function to support and enclose the more important and more delicate structures which are contained in the alveoli, as well as the lymph vessels and blood vessels which belong to them. Thus the alveoli along with the tubular channels of communication between them form one many-chambered cavity, which cavity is occupied by a structure of the same contour as itself, attached to it, as I have said, by innumerable threads or bands of extreme tenuity. This compound body might be compared to a bunch of grapes in which each little stalk joins some other, instead of all combining to form one principal stalk; the stalks (which receive the name of medullary cylinders), being attached to the communicating channels in the same way as the ampullæ are to the alveoli.*

Such being the general arrangement of the alveoli and their contents, it remains to advert to their relations to the lymph stream, and the formation of lymph corpuscles, a subject which has a close relation to the pathological process it is our present object to study. The ampullæ as well as the medullary cylinders consist of a network of extreme delicacy, the interspaces of which are entirely occupied by lymph corpuscles. The ampulla is not covered by any membranous investment, the only difference between the surface and the enclosed pulp being that at the outside the meshes are much smaller, and the minute fibres are much more closely felted together than they are towards the centre. Nor is there any distinction, as regards the structure of the fibres themselves, between those which form the fine meshwork of the ampullæ and those which form the fibres by which they are suspended to the internal surface of the alveolus, excepting that the latter are somewhat coarser.

From the examination of glands naturally or artificially injected it has been ascertained that the afferent lymphatic vessels, after they penetrate the capsule of the organ, spread over the surface of the

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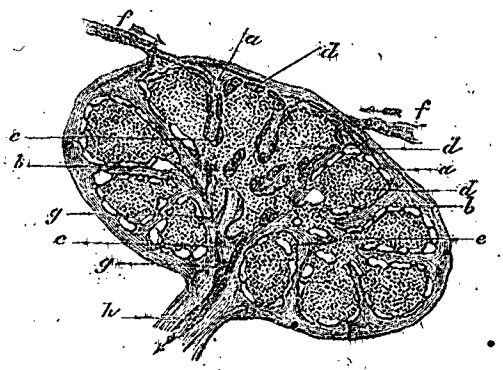
* In illustration of the description in the text, the following diagrammatic section of a lymphatic gland, copied from Frey, may be of service :—



a, capsule; *b*, dissepiments between the *alveoli*, all of which are continuous with the capsule and converge at *c* towards the *hilus*: *d*, *ampullæ*; each *ampulla* occupies an *alveolus*, to the surface of which it is attached by bands or threads, which cross the lymphatic sinuses; *e*, medullary cylinders; *f*, afferent lymphatic vessels; *g*, efferent lymphatics, uniting at the hilus into one trunk, *h*.

adjacent medullary substance, finding their way immediately to the spaces surrounding the ampullæ and their connecting cylinders. How the lymph sinuses open into the numerous and minute lymphatic branches which combine to form the efferent trunks is not even now accurately determined. The fine network of the ampullæ is richly supplied with vessels, the arrangement of which in relation to that structure may be seen in Plate IV., Figs. 2 and 3 (see explanation). The arteries from which these capillaries derive their supply enter the reticular tissue by penetrating the medullary cylinders, and continue their course along the axes of these cylinders towards the ampulla, each being usually accompanied by a vein.

From the preceding short sketch of the anatomy of the lymphatic glands, which I have verified in its leading particulars in the lymphatic glands of guinea pigs, it appears that in their relation to the adenoid tissue which constitutes the ampullæ and cylinders, there is a complete antagonism between the lymphatic and blood circulation. Whereas the blood capillaries are richly distributed throughout the adenoid tissue, the lymph stream is separated from it by the densely felted fibres within which that adenoid tissue is comprised.

Adenoid pulp of Peyer's follicles and of the *Trachom-drüsen.*

It is now well known that Peyer's follicles have a structure which, although simpler, altogether resembles that of the ampullæ of the lymphatic glands. A Peyer's follicle is a mass of adenoid pulp of which the projecting part is covered by epithelium, while the convex under surface is surrounded by a lymph cavity, which can be injected from the lymphatic system, corresponding in every respect to the alveolar sinus of a lymph gland, the only difference being that whereas no epithelium can be detected in the latter, it has been distinctly made out in the former. Along the intermediate zone (so-called equator) the adenoid pulp of the follicle is continuous with the similar tissue of the sub-mucous layer. Peyer's follicles, like those of the lymph glands, are abundantly supplied with capillary blood vessels which have the same arrangement precisely as in the ampullæ.

Similar adenoid follicles are met with in other parts of the body. Thus in the conjunctiva there are globular masses of vascular cytogenic pulp (*Trachom-drüsen*), each of which is partly surrounded by a lymph sinus, just in the same way as the ampullæ of the lymphatic glands. In the adenoid follicles of the tonsils and in the follicles at the root of the tongue, which in every other respect closely resemble the others, this relation has not as yet been made out.*

Adenoid pulp of the spleen.

In the spleen we have an organ in which adenoid tissue exists in larger proportion than even in the lymphatic glands. Its relation, however, to the blood vessels is entirely different. It can be readily made out in the guinea-pig that, although the largest arteries are surrounded by common connective tissue, the rest are provided with sheaths of adenoid tissue which closely resemble the medullary cylinders of the lymphatic glands, and that the malpighian corpuscles are formed by the outgrowth of these cylinders into the form of spheroidal tubera, which either surround them, or project from them laterally. As is well known, the arteries very rapidly divide, first into small arterioles and then into minute capillaries, some of which go to the malpighian corpuscles, others to the so-called pulp. Of this pulp all that can be said is that it is an exceedingly fine adenoid reticulum, which fills the whole of

* Bruch, Zeitsch. f. w. Zool. B. iv. p. 297, 1854.

the space not occupied either by the malpighian corpuscles, or by the venous channels which permeate the spleen in all directions. What becomes of the arterial capillaries in this tissue has been until lately an open question, for it has long been recognized that they do not communicate directly with the veins. The recent investigations of Frey seem to show in the most conclusive manner that they actually lose themselves in the adenoid reticulum through which the blood filters into the innumerable venous channels which pass in all directions through the pulp. It is interesting as well as important to notice that in the spleen just as in the lymphatic glands, the three tissues of which it is constituted are not separated from each other by any membrane. The whole arrangement of the organ depends on the form of the reticulum, which is everywhere of the same nature, differing only in the degree of tenuity of the fibres and the size and form of the meshes, so that the reticulum of the malpighian corpuscles, of the arterial sheaths and of the pulp, constitute but one framework continuous throughout.

Distribution of adenoid pulp in the mucous and serous membranes.

In all the instances hitherto referred to the adenoid tissue forms whole organs, the functions of which depend on the reaction of the tissue itself on the blood or lymph which circulates through it. But there are other parts of the body in which the same structure is to be found, not consolidated into masses of definite contour, but scattered in layers which for the most part lie underneath or form part of the skin and mucous and serous membranes. It is necessary to study these adenoid expansions, with reference to the reaction upon them of the tuberculous infection. The field of research is so large that the view I am able to give of them must be necessarily incomplete.

Peritonæal adenoid tissue.

In my last report I described certain bodies as existing in relation with the arteries of the omentum of animals infected with tubercle, in the form of nodules, varying indefinitely in size, the largest being comparable to hempseeds. From the more minute and careful examination of them which I have since made, I have learnt that these visible granulations are strictly speaking not new growths but overgrowths, and that they originate by the enlargement of previously existing organs, not by the development of any heterogeneous structure. These organs have been little noticed by anatomists. The only reference which I find to them is in the last edition of Prof. Kölliker's "*Handbuch*" (p. 603), where he describes certain globular prominences consisting of cells resembling lymph corpuscles along with proliferating epithelium cells, as always to be found on the surface of the human peritonæum, and particularly of the *omentum majus*. Further, Dr. Knauff of Heidelberg, in two very recent papers,* describes certain organs under the designation of "lymphatic nodules," as constantly to be found in many parts of the serous membranes, and clearly recognizes the close relation between them and miliary tubercle. To these researches I shall have further occasion to refer, and content myself for the present with remarking that my own observations were complete before I became acquainted with them. It is probable that organs of the same kind exist not only in the pleura and peritonæum but also in synovial membranes, and they have a close relation with the villous structures which border the articular cartilages.

In the peritonæum of the guinea pig I have studied these bodies,

* Knauff, Zur Histologie des Miliartuberkels auf serösen Häuten (vorläufige Mittheilung). Centralblatt, Aug. 17, 1867. Knauff, Ueber das Pigment der Respirations Organe. Virch. Arch. vol. xxxix. p. 443.

chiefly in those parts of the membrane which are the constant seat of tuberculous disease, viz., in the omentum and in the double fold of membrane which encloses the pancreas, and extends from that gland to the greater curvature of the stomach and the duodenum in its long course from the pylorus to the orifice of the pancreatic duct. These layers are continuous in front with those which in this animal go to form the omentum, a structure which differs widely from the omentum majus of human anatomy, both in its position and relations. Instead of stretching as a veil over the mass of intestines, it occupies a concealed position along the greater curvature of the stomach, to the convex surface of which it not unfrequently adheres. In order to examine these structures satisfactorily, the best method is to open the abdominal cavity from the front, and fill it with serum or some other indifferent liquid. By this means the omentum, which is of extreme delicacy, can be made to float, and thus dissected out without risk of injury. My invariable plan is to sever the peritonæal attachments of the spleen and pancreas on all sides under liquid, and then to remove the two organs together, and spread the membranes on a large plate of glass for examination under the dissecting microscope.

The omentum consists in its most transparent parts of two layers of epithelium, enclosing a regular network of connective fibres, the meshes of which are remarkably uniform in size, measuring about $\frac{1}{400}$ of an inch. The epithelium is formed of cells with wavy outlines, each containing a spheroidal and finely granular nucleus. These cells cling closely to the fibres of the network, never extending over the empty spaces between them, in consequence of which the nuclei project visibly from the surface. The relation of the arteries and veins to these two essential elements of the structure, viz., the epithelium and the network of structureless transparent fibres, differs according to their size. The smallest vessels, whether venous or arterial, are in immediate contact with the epithelium (see Fig. 2, Plate VI.). The vascular wall is connected on either side with the fibres of the network, with the substance of which it appears to be intimately blended. The larger vessels are enclosed in sheaths, of which, although they vary considerably in their structure according as they are studied in the omentum or in the mesentery, two principal varieties may be distinguished, those which contain fat cells, and those which consist entirely of adenoid tissue. Of the first kind a complete idea may be gained from Plate II., Fig. 1, which represents a vascular anastomosis from the mesentery. Each artery with its accompanying vein is enclosed in a flattened cylinder, of which that part which is next the vessels consists of fat cells, whereas the external part is of transparent adenoid tissue which could not be distinguished from that of a lymph gland. Vessels of size intermediate between those last described and capillaries lie in a mass of adenoid pulp, which sometimes forms a tubular sheath of uniform diameter, sometimes projects from the serous surface in the form of fringed appendages, extending along the course of the vessel, or spreading out between the epithelial layers.

From the masses of adenoid pulp which surround or fringe the vessels, to the adenoid nodules previously referred to, the transition is easy. These bodies are in fact collections of the very same material. They occur in the peritonæum in a variety of forms, of which the following are examples:—

Form a. Mere aggregations of cells, between the opposed layers of epithelium, not supplied with vessels. These occur very frequently in the omentum, in some parts of which they exist in great numbers.

One of them is shown in Plate II., Fig. 3. The lymph corpuscles are seen to be embedded in the substance of the same transparent material as that of which the fibres of the omental network are composed, which have become blended together into a hyaloid capsule of an oval form for their reception. These non-vascular nodules are usually much larger than the one represented, which was selected in order that the whole of it might be comprised within the field of the microscope.

Form *b*. Collections of cells around loops of intermediary vessels. One of these is shown in Plate I., Fig. 4. An arteriole after leaving a larger trunk runs a short course between two opposed layers of epithelium, towards a mass of adenoid pulp. From this mass a vein *larger* than the artery returns by the same course.

Form *c*. An arteriole (Plate I., Fig. 1 *a*.) terminates in a labyrinth of capillaries not at all unlike a renal malpighian tuft, out of which the vein emerges, and after joining another vein from a similar tuft soon finds its way to a venous trunk. Other forms might be referred to, but most of them are modifications of those already described. In intimate structure the vascular sheaths and isolated masses are alike. All are collections of lymphoid corpuscles embedded in an extremely delicate reticulum and covered with epithelium.

The epithelium covering the adenoid masses is continuous with the general epithelial lining of the peritonæal cavity, but differs from it materially. Plate VI., Fig. 2, illustrates the fact that wherever a capillary artery or vein occupies the space between the two layers of epithelium, the epithelial elements not only become more or less oblong, but arrange themselves in a direction parallel with that of the axis of the vessel. When larger vessels lie immediately underneath the surface the same arrangement is observed. Fig. 4 on Plate II. shows the epithelium covering an artery and vein, which are bordered on either side by an adenoid fringe. Over the whole of the fringe the epithelium can be traced, but it is seen that the form and size of the elements are different; instead of being large oblong plates with sinuous margins, they look like round scales. This appearance corresponds evidently to the proliferated epithelium of Kölliker. It is to be found without exception over every mass of adenoid tissue when examined by v. Recklinghausen's method; but in preparations stained with carmine it cannot be recognized, the nuclei of the epithelial elements when coloured by that reagent looking exactly like lymph corpuscles.

The relation of the adenoid tissue to the vessels has been investigated by two methods. In some of the experiments, I injected a solution of carmine containing one drachm in two ounces of water, about two hours before killing the animal, into the peritonæal cavity, in the manner practised by Prof. Chrzonszczewsky of Kasan. The effect of this process is remarkable; all the masses of adenoid pulp are coloured, so that in those parts of the peritonæum in which they are numerous the surface looks as if it were scattered with red dots. Under the microscope it is seen not only that the lymph corpuscles are stained, but that the veins leading from them are filled with carmine. These appearances at first suggested that the distended channels were in truth not veins but lymphatics, but on tracing them to their destination I soon satisfied myself of their real nature. By this method I also learnt that wherever the adenoid pulp is in relation with blood vessels, it is itself richly supplied with blood. These capillaries are so large that when the tissue is examined in glycerine they often seem to constitute the whole mass, completely concealing the cells. Whether they communicate or not directly with the arteries, or like the venous channels of the

spleen receive their blood from inter-corpuscular spaces, seems to me to be a question yet to be determined. With reference to it, it is to be noticed that the capillaries demonstrated by this method can always be traced into efferent venous trunks, but cannot, so far as I am able to observe, be shown to be continuous with arterioles, and that the efferent vessels are always either larger or more numerous than the afferent. In addition another fact is to be borne in mind, which although mainly pathological, may not be exclusively so, viz., that the veins leading from adenoid masses are, when the latter are excited by the tuberculous infection, often filled with colourless corpuscles (see Plates I. Fig. 3, and VIII., Fig. 4). So far as relates to the vascularity of adenoid tissue in the diseased state, my injections of the diseased parts from the cœliac axis show that the tissue is richly supplied with arterial capillaries, the arrangement of which cannot fail to remind one of the manner in which the arterial capillaries of the spleen are distributed to the sheaths of adenoid pulp. As regards the relation of the adenoid masses in the peritonæum to the lymphatic vessels, I confess myself to be entirely at fault. In applying v. Recklinghausen's method, I have failed to discover any lymphatic channels, nor am I aware that anyone else has met with them in this part of the peritonæum.

Physiological signification of the adenoid tissue of the peritonæum.

The above details render it possible to enter on the consideration of the physiological significance of these masses. From their structural analogy to the splenic pulp, it is scarcely possible not to suppose that they have similar functions, *i. e.*, that they are concerned in the elaboration of blood corpuscles, while, on the other hand, their resemblance to the adenoid structures of the mucous membranes suggests that they are probably concerned in absorption, and that they stand in the same relation to the peritonæal cavity that Peyer's follicles and the rest of the adenoid tissues of the intestine do to the alimentary canal. The latter view seems probable, from the similarity of the conditions under which they show signs of excited action with those which affect, in a corresponding manner, the lymphatic glands and the intestinal follicles. In animals that have died of acute peritonitis all these adenoid masses become soft, tumid, and enlarged.* If the smallest possible amount of tuberculous material, suspended in water, is injected into the peritonæum, these organs undergo a more gradual hyperplasia, and eventually become tuberculous. This delicacy of reaction against an infective agent seems to me to be more easily understood by supposing that the morbid material actually passes through the excited tissue than in any other way.† In suggesting that the peritonæal adenoid masses, as well as adenoid tissues everywhere, play an important part in the development of the blood corpuscles, I am partly influenced by the observation already referred to, namely, that under certain circumstances not fully determined, colourless blood corpuscles are contained in extraordinary numbers in the veins leading from them, and partly by my inability to think of any other final cause for their existence. I have been further

* In confirmation of this statement, see an observation published by Professor Klebs since the above was in print, who has observed the same fact, but attributes it to emigration from the capillaries of colourless blood corpuscles! Klebs, Handbuch der pathologischen Anatomie, 1869, p. 318.

† In confirmation of this conclusion I would refer to the following experimental result (March 31st). In three guinea pigs inoculated 21 days previously, by the injection of a drop of distilled water rendered turbid with pounded diseased lymphatic gland, no lesion was found excepting that the adenoid masses (Knauff's bodies) in the anterior mediastinum were enlarged to such an extent that when the membrane was spread out on a glass plate, they could be readily distinguished without the aid of a lens, as transparent beads.

very strongly confirmed in my surmise since I have become acquainted with the recent most important researches of Neumann as to the development of blood corpuscles in the cytogenic tissue of the medulla of bone, and the still more satisfactory observations of Bizzozero on the same subject.*

In the alimentary canal adenoid reticular tissue is very generally distributed underneath the mucous surface, and wherever it occurs it has important relations with infective morbid processes. In addition to the follicular glands analogous to those of Peyer, which have been already referred to,† there are masses or layers of the same material in the mucous membrane of the fauces and pharynx as well as in that of the small intestine. In the latter situation, indeed, adenoid pulp constitutes the great bulk of the mucous tissue, forming a continuous stratum the deep surface of which is separated from the muscular fibres by the connective tissue and vessels, its upper limit being the so-called basement membrane of the epithelium, with reference to which it is now known that it is not in any true sense a membrane, but is merely due to a superficial condensation of the delicate reticulum which pervades the whole mass. Everywhere throughout the small intestine the adenoid pulp is in relation with the submucous network of lymphatic channels, which over the whole of the villous portion of the small intestine are of great width and exceedingly numerous.‡

The mucous membranes which line the respiratory cavities, and particularly the pulmonary air tubes, possess no adenoid tissue resembling that of the alimentary canal. In the guinea pig, as in other mammalian animals, longitudinal elastic fibres and transverse muscular fibres lie immediately underneath the epithelium of the bronchial tubes, outside of which comes a layer of common connective tissue, in which more or less imperfect cartilaginous rings are enclosed. Anatomists have not described any glandular structures excepting the acinous mucous follicles which occur here and there beneath the mucous membrane of the larger bronchi.

Distribution of natural adenoid pulp in the healthy lung.

In my former report I stated that in the irongrey nodules which result from tuberculous inoculation two kinds of cells are met with, namely, large nucleated cells which I identified with those naturally contained in the alveoli, and smaller bodies not much larger than blood corpuscles, which I regarded as the essential elements of the morbid growth. Following out the line of inquiry which my observations as to the development of tubercle in the peritonæum had suggested, I devoted much attention to the examination of the healthy lung in the guinea pig, for the purpose of ascertaining whether or not masses of adenoid pulp are to be found in it, particularly in those parts which appear to be the favourite starting points of tubercle.§ From the examination of a number of specimens, I have ascertained that masses of cytogenic tissue of irregular form are always to be found in the neighbourhood of the bronchi. Those which are in relation with the smaller branches lie in the loose

* Neumann, Bedeutung des Knochenmarkes für die Blutbildung (vorl. Mittheilung), Centralblatt, Oct. 10, 1868. Bizzozero, Sulla funzione ematopoietica del Midollo delle Ossa. Gaz. Med. Ital. Lombard. 1868, No. 46.

† See Huxley on the Tonsillar Follicles, Microscopical Journal, vol. ii. p. 74. See also von Luschka. Das adenoide Gewebe des menschlichen Schlundkopfs, Schultzes Archiv., B. iv. 1–9.

‡ For a complete and exhaustive account both of the tissue itself and of its vessels, see Frey, "Ueber die Chylusgefässe der Dünndarm-schleimhaut, und über die Lymphbahnen der Peyer'schen Drüsen," Zeitschrift für w. Zoologie, B. xiii. S. 1–28.

§ The only structures containing adenoid tissue which have been referred to by anatomists as existing in the lung are the so-called *glandulæ pulmonales* (lymphatic glands in the neighbourhood of the larger bronchi).

common connective tissue by which these tubes as well as the blood vessels are separated from the air cells, while those which lie near bronchi of sufficient size to be possessed of cartilages, are found to lie in a corresponding position outside of the fibrous layer in which the cartilages are embedded. In every instance I have found the adenoid masses occupying a position between the air tube and the nearest artery, with the outside of the adventitia of which the surface of the mass is usually, if not always, found in contact. It was never, however, observed that the arterial adventitia was in the slightest degree modified, so that the mass could not be regarded as a development from that structure. It is further to be noticed that in injected lungs the masses were found to be vascular, minute capillaries not only ramifying on their surface, but penetrating into their interior. I am unable to state anything from my own observations as to the relation of these bodies to the lymphatic system; but inasmuch as they lie in the course of the absorbent vessels (see p. 116), I have no doubt that they are in direct relation with the lymph stream. (See Plate V., Figs. 2 and 3, and Plate VIII., Fig. 3.) From their position relatively to the bronchi and arteries, it became evident to me that these normal masses of adenoid pulp correspond anatomically to the much larger abnormal collections of similar material which in my last report I described as peri-bronchial granulations.

In the liver, strata of adenoid pulp are also to be found in the healthy condition of the organ, the distribution of which is analogous to that which I have described above. The tissue stands in the same relation to the branches of the portal vein and the bile ducts that it does to the pulmonary arteries and bronchi. I have not, however, as yet met with definite masses like those which are to be seen in the lungs, nor am I able to state how far the tissue can be traced along the ramifications of the portal ducts. It cannot, I believe, be demonstrated in the interlobular spaces.

Additional Observations as to Tuberculosis of the Lymphatic Glands.

I have now to bring the anatomical facts stated in the preceding paragraphs into relation with the morbid processes which constitute tuberculosis. In doing so, it is clearly most advantageous to consider those which have their seat in the lymphatic glands and in the spleen, not merely because I gave only a general and preliminary account of them in my last report, but because the reaction of the tuberculous infection on the *normal* adenoid tissue of which these organs so largely consist, is the type and pattern of the changes to which the similar *adventitious* tissue is subject elsewhere.

The diseased conditions of the lymphatic glands (excepting so far as their rough pathological anatomy is of practical interest to the surgeon) have been very little studied, so that in beginning the investigation of any of them one is breaking new ground. The reason why so little is known of the subject is obvious; until lately their normal structure was not understood even in its broad outlines.

My dissections have all been made by the process first, I believe, employed by Billroth, about ten years ago, and subsequently so successfully and so extensively applied by His, to the investigation not only of the structure of the spleen and lymphatic glands, but of many other organs—the method of pencilling out thin sections of the hardened tissue with a sable brush held vertically. Fresh sections of the spleen or lymphatic glands, whether prepared with the double-bladed knife or otherwise, show absolutely nothing of the structure. All that can be seen is a confused mass of cells. Sections of the same organs, after hardening

in chromic acid or alcohol, are much more instructive, but still the observer is embarrassed by the innumerable multitude of cells, which seem so closely packed that there can be no room for any other elements. By pencilling such a section in the manner above referred to, a vast number of these bodies are removed, whereas, if proper care is taken, the reticulum in the meshes of which they are contained remains unaltered. The application of this method in the investigation of the lymphatic glands is specially valuable, for it affords a ready means of differentiating the two principal textures which enter into its composition—the medullary and the cortical—and of bringing into view the ampullæ with their surrounding lymph-sinuses.

The lymphatic glands are subject to two distinct morbid alterations in tuberculized animals, both of which were referred to in my former report as affecting subcutaneous and internal glands respectively. The subcutaneous glands are affected only secondarily, that is, in consequence of local changes going on at the seat of injury, consequently none of them become diseased excepting those that receive tributaries from diseased parts. The morbid changes produced are more or less acute and lead to softening and suppuration. The alteration consists in enormous and rapid enlargement of the organ, consequent on multiplication of cells. The alteration appears to affect all the parts of the gland alike, but does not in its early stages alter its structure. It may be said to consist primarily mainly in congestion, and in the multiplication of cells in such enormous numbers as to destroy the consistence of the gland. Minute collections of free cells (purulent foci) become disseminated throughout its substance, by the confluence of which the whole is converted into an abscess. In the meantime the capsule of the organ becomes thickened by the interstitial development of new connective tissue, within which may usually be found a layer of gland-substance, which instead of softening has undergone the gradual process of induration to be immediately described.

In the internal lymphatic glands the origin of the morbid alteration is always tertiary—that is to say, it is a consequence of secondary disease existing in the organs from which they receive their afferents. These alterations are chronic in their character, and are never attended with suppuration. I have studied them principally in those glands which receive the lymphatics of the liver, and are situated in the *ligamentum hepaticoduodenale*, close to the portal vessels. The changes observed are of the following nature. In the early stages nothing is seen excepting that the alveolar reticulum is perhaps somewhat coarser than it should be. (Plate IV., Figs. 1 and 2.) All the constituent parts of the organ can be readily distinguished from each other, and the lymphatic sinuses seem to be pervious and in a natural state. The further progress of the alteration is marked by the diminished distinctness of the structure. It becomes more and more difficult to distinguish the alveoli from the trabecular tissue by which they are separated from each other. This appears to arise from two distinct processes. In the first place, cells are developed in great numbers in the fibrous tissue which constitutes the external capsule of the organ as well as the septa or partitions which separate the alveoli from each other. These cells differ from the ordinary lymph corpuscles in their larger size, and in the fact that most of them are distinctly nucleated. They are arranged in round or oblong groups enclosed in the meshes of the fibrous tissue, or more properly speaking, in cavities which they have made for themselves. In this way the trabecular tissue loses its natural compactness, and assumes the character of a spongy reticulum, the interstices of which, however, are

much larger than in that of the alveoli. In the ampullæ a change occurs which at first sight appears to be of an opposite nature. The slender fibres of the alveolar reticulum become coarser. Towards the centre of the ampullæ this thickening seems to affect all the fibres equally, so that a fine network of threads is converted into an equally fine network of transparent cords, the holes of which, notwithstanding the general enlargement of the whole mass, are much smaller than they were before. Towards the surface of the ampullæ the process consists in the formation of irregular bands of fibrous material traversing the original tissue at various distances and in various directions, by which the lymph spaces are obliterated and the whole converted into a coarse sponge, and thereby assimilated to the altered cortical tissue with which it is continuous. All this might be expressed more shortly but less completely by saying that the whole of the medullary part of the gland becomes the seat of fibrous degeneration, which, while it principally affects the dissepiments, extends from them to the alveoli, converting all the affected parts into a fibrous sponge in the interstices of which are contained cells usually larger and more distinctly nucleated than lymph corpuscles.

Up to this point the altered gland tissue is still supplied with blood, for in specimens of which the arteries are injected it may be seen to be pervaded with vessels in all directions. The vascularity, however, is I believe confined to the trabecular tissue, for the fibrous degeneration of the fine tissue of the ampullæ necessarily involves the obliteration of its equally delicate capillaries, or rather their conversion into fibrous bands indistinguishable from the rest of the tissue. The part which the corpuscles take in this process of fibrous transformation must, I venture to think, be exceedingly subordinate. In the ampullæ the natural lymph cells totally disappear, so that in those parts of the gland in which the fibrous change is most complete there are no cells whatever, as one may easily satisfy oneself by the examination of unpencilled sections. In those parts where there are still heaps of cells contained in the meshes of the sponge, these appear to have nothing to do with the development of the fibres which surround them. The ultimate result of the process is caseation, *i.e.*, slow necrosis. The fate of the cells is to die, of the fibres to become opaque and granular. Why this happens scarcely needs explaining. For even if we refuse to admit that an adventitious tissue is in itself less alive than the tissue which it replaces, the mechanical effect of such a transformation as has been described must be to produce anæmia and consequently slow death. As to the chemical nature of the material deposited I have little to say. It is very translucent, never striated or granulous, and is very readily stained by solution of carmine.

The relation of the morbid process to the functions of the organ can scarcely be doubted. From the moment that the intra-alveolar network becomes transformed into ordinary fibrous tissue, all activity must be at an end; as the degeneration progresses the lymph stream must be entirely stopped, and all the tributaries leading to the gland obstructed. Thus in every case in which a diseased organ induces fibroid degeneration of its lymphatic glands, those glands must react on the organ itself by obstructing its lymphatic capillaries.

The changes which occur in the spleen correspond so closely with those observed in the lymphatics, that they scarcely need a separate description. The development of the disease is divisible into two stages. It begins, as in the lymph glands, by a rapid cellular proliferation, in consequence of which the organ increases enormously in size. The

multiplication of cells occurs, as I stated last year, principally in the malpighian corpuscles, in consequence of which these bodies become unnaturally prominent and obvious, and assume in every respect the character and appearance of miliary tubercles. By the overcrowding of the cells the blood vessels are compressed, so that the central parts become anæmic and undergo caseous degeneration. Eventually the spleen undergoes a fibroid degeneration, the characters and results of which are similar in every particular to those already described in the lymphatic glands. The pulp and the malpighian corpuscles, which in the guinea pig are remarkably well developed, especially underneath the convex surface, and form by far the greater part of the bulk of the organ, soon become indistinguishable. This blending of dissimilar types of structure takes place just as in the lymphatic glands. On the one hand the capsule is everywhere thickened, and here and there bulges out into nodular prominences in consequence of the irregular growth of groups of cells in the interstices between its fibres, while on the other the bands of newly formed fibrous material spread in every direction through the pulp. The final result of the transformation resembles that which I have already described so closely, that if it were not for the more regular arrangement of the trabeculæ it would be impossible to discriminate between sections of the two organs (see Plate VII., Figs. 5 and 6).

Additional Observations as to Tuberculosis of the Skin.

As to the primary local effects of inoculating tubercle or of introducing other irritants into the living tissues of the guinea pig so as to induce tuberculosis, results of great importance have been recorded by other observers,* and particularly by Dr. Fox, since the date of the last report. In Dr. Fox's experiments the foreign matter was inserted under the skin. He admits that the most common local result is the formation of masses of cheesy matter which are dry and friable, ("débris of fattily degenerated material,") and are enclosed in capsules of firm semi-transparent and almost lardaceous appearance. But in addition to these encapsuled masses of caseous matter, he states "there are small granulations "varying in size from that of a poppy seed to that of a hemp seed, "which are irregularly scattered for a variable area in the subcutaneous "tissue." With respect to these masses, which are sometimes semi-transparent throughout, and sometimes have opaque centres, he remarks that "they present a striking resemblance to the naked eye, and also "under the microscope, to the changed lymphatic glands." The account he gives of their minute structure may be summarized as follows:—In their denser and more central parts they consist of nuclei embedded in an homogeneous tissue, in their less dense parts "a fibrillated tissue "which forms bands or trabeculæ between which the cells lie," the whole forming a structure which has "the strongest resemblance to the "elementary composition of a lymphatic gland, or to the cytogenic "tissue of His." "Throughout the granulations many of the cells "and also of the nuclei are seen in various stages of fatty degeneration. "The fat is sometimes in visible drops, sometimes in a finely molecular "form. The change is most common towards the centre of the granu-"lations, but it is also seen in cells irregularly scattered through the "adjacent tissue."

Of these subcutaneous granulations but little notice has been taken

* See Klebs, Ueber die Entstehung der Tuberculose u. ihre Verbreitung im Körper. Virchow, B. xliv. S. 242. Langhans has introduced the infective material beneath the conjunctiva of the eye, Klebs and Cohnheim into the peritonæal cavity. I have been unable to obtain a copy of Langhans' researches which are contained in an inaugural dissertation.

by other observers.* Their importance was overlooked in the account given of the local changes in my last year's report. Investigations which I have made with special reference to this subject enable me to confirm in every particular the accuracy of Dr. Fox's details. In animals that have been inoculated from three to four weeks with material taken immediately after death from the bronchial glands of other tuberculized animals, the only morbid alteration which can be discovered consists in the existence of a knot of hardened and thickened skin. On making a section of the diseased part, and examining it with a lens, it is seen that the hard mass lies immediately under the true skin, of which in fact it seems to form a part; and that it consists of an aggregation of smaller masses, separated from each other by more or less irregular bands of connective tissue. At a later period, that is to say, seven or eight weeks after inoculation, other nodules are found in the neighbourhood of the original one, which, excepting that they are more disseminated, resemble the little masses already referred to, each being enclosed in an indistinct capsule of reticular connective tissue similar in character to that which enters into the composition of the nodule. On examination of the smallest of these granulations in the recent state, nothing can be discovered excepting that it is a mass of round cells like lymph corpuscles. In sections of hardened tissue it is found that these corpuscles are enclosed in a fine meshwork of fibres. I have never seen this meshwork comparable in fineness to the alveolar reticulum of a healthy gland, from which, indeed, it differs in several important particulars. Not only are the septa thicker and coarser, but even in the smallest and presumably youngest granulations each cavity is large enough to contain several cells, whereas in the ampullary network the threads are never further apart than the diameter of a single corpuscle. If, however, the comparison be made between the adventitious tissue and the coarser network which occupies the lymph sinuses in the lymphatic glands, the resemblance is much closer, and it is still more striking as regards a lymphatic gland in incipient fibroid degeneration; so complete, indeed, is the correspondence of structure that the two are indistinguishable under the microscope. (See Plate VII., Figs. 3, 4, 6.) The cells which occupy the spaces between the fibres are for the most part similar to lymph corpuscles; in some no distinction can be seen between nucleus and cell, while in others there is a nucleus surrounded by a mass of less refractive matter, not much larger than itself. In addition to these ordinary lymph corpuscles I have always found a certain number of much larger nucleated cells, exact representations of which are given in Plate VII., Fig. 3 *a. b. c. d.*

In pencilled sections of single nodules it is found that the meshes of the network are much smaller in the centre of the granulation than near its periphery, so that in the latter situation there are open spaces not crossed by fibres of the reticulum, large enough to contain a considerable number of corpuscles, which can be as easily pencilled out of them as out of the medullary lymph spaces of the lymphatic glands. Of the relation of these subcutaneous nodules to the lymphatic capillaries I regret to say that I know nothing, as I have altogether failed to trace these vessels in the diseased tissues. Guided by the analogy of the adventitious to the natural adenoid structures, it seems extremely probable that the lymph stream passes through the peripheral network of the nodules in the same way that it does through the sinuses of the lymphatic glands. Sections under a low power show very distinctly

* Professor Lebert makes some reference to them in his paper on the communication of tubercle to animals in Virchow's Archiv., vol. xliii. They are also vaguely referred to by Villemin.

that these nodules are in the closest relation with the closely packed connective tissue in which the hair bulbs and cutaneous glands are embedded; they are separated from it, however, by a sharp line of demarcation.

In the loose connective tissue between the muscular and tendinous layers it is common to find minute granulations, some of which are so small as to require a lens for their detection. On superficial examination these might be regarded as of the same nature with those found in the cutis. That they are really inflammatory in their origin is indicated by the large size of the cells, and their obvious development from connective tissue corpuscles, as well as by the absence of any reticulum. I have never observed any change in the muscular or tendinous tissues themselves. (See Plate VII., Fig. 2.)

Observations relating to the Lymphatic Capillaries.

Until the publication of v. Recklinghausen's researches in 1862* it was not known by what sort of channels the lymphatic system commenced. In the few tissues in which anatomists had succeeded in filling them with injection, most observers, including Brücke and Ludwig, regarded them as mere interstices not lined by any membrane. v. Recklinghausen not only proved the existence of lymphatic capillaries but demonstrated their structure by the method to which I have already had occasion to refer. This method consists in subjecting the tissue to the action of an extremely weak solution of nitrate of silver (either by injection or imbibition) for a few seconds, and then exposing it to the light, by which means the chloride of silver first deposited in the substance of certain elements of the tissue assumes a reddish-brown colour. When this method is successfully applied to the examination of the lymphatics, a mosaic of dark-brown lines, (see Plate VIII., Figs. 1 and 2,) is brought into view; these lines correspond to the edges of the epithelial plates, or more properly to the interstitial cement which separates them from each other.

The arrangement and structure of the lymphatic capillary channels have now been satisfactorily made out in almost all the internal organs—in the lungs (Wywodsoff), in the liver (MacGillavry and Chrzonszczewsky), in the mucous membranes (His and Frey), in the pleura (Chrzonszczewsky, Afonassiew, Dybkowsky), in the peritonæum (v. Recklinghausen and Schweigger-Seidel). With respect to the last-mentioned structures, the original discovery of v. Recklinghausen that the serous cavities communicate with the lymphatic vessels, has been confirmed by the observations of Schweigger-Seidel and Chrzonszczewsky as regards the communication of the peritonæum with the superficial network of the lymphatic capillaries on the under surface of the diaphragm, by Dybkowsky as regards the costal pleura, and by Afonassiew as regards the pulmonary pleura; so that there can now be no doubt that these great cavities play a most important part, not only in the physiology of absorption, but in the diffusion and distribution of infective materials.

I have already stated that in the skin I have entirely failed in tracing the relation of tuberculosis to the lymphatic capillaries. Professor Klebs (of Berne), however, has been more successful.† His observations, although few in number, are clearly of great importance in their bearing on the question whether or not the absorbents are to be regarded as the channel by which tuberculous infection is conveyed. His principal ex-

* v. Recklinghausen, Die Lymphgefässe und ihre Beziehung zum Bindegewebe. 4to., Berlin, 1862.

† Klebs, loc. cit. p. 285.

perimental results are as follows: a liquid consisting of finely comminuted cheesy tubercle from the lungs of a phthisical patient was injected in extremely small quantity with a hypodermic syringe into the peritonæal cavities of three guinea pigs. They were killed at periods of 30, 43, and 70 days after inoculation. In the first, miliary tubercles were found in the peritonæum at the point of insertion, in the serous investment of the liver, spleen and kidneys, in the diaphragm and in the lungs. In the second, the peritonæal lesions were similar but more extensive, in addition to which the mesenteric and bronchial glands were much diseased. In the third animal some of the organs affected in the preceding cases, and particularly the lungs, were free from disease, but the alteration of the bronchial glands was much more advanced, from which he concluded that they were infected directly from the diaphragm. In each case Klebs applied the method of v. Recklinghausen for the investigation of the condition of the lymphatics. It was found that the nodules, which were confined to the peritonæal surface, were smallest and most numerous on the *centrum tendineum*. In the most minute of these miliary granulations a very distinct relation could be traced between the arrangement of the cells of the new growth and the rectangular network of lymphatic capillaries, (discovered by v. Recklinghausen,) which lies under the epithelium. It was observed that wherever there were tubercles the network was interrupted, and that the smallest tubercles were often situated at the junction of several lymphatic channels. The author admits that the tuberculous mass spreads into the intermediary substance (*Grundsubstanz* of v. Recklinghausen), between the lymphatic channels, but states that at the edge of each granulation it "stretches out in processes," each of which corresponds to a lymphatic channel, within which he infers the new growth must have originated. He further believes that the epithelium of the lymphatic capillaries, which here as elsewhere consists of oblong plates with wavy contours, each containing an oval nucleus much smaller than itself, is transformed into "tubercle corpuscles;" or in other words that there is a proliferation of the lymphatic epithelium, similar to that which Rindfleisch * supposes to occur in tuberculosis of the omentum—the newly-formed cells first filling the lumen of the vessel and then bulging it out so as to take the place of the intermediary substance.

On the 24th of October I inoculated several guinea pigs by the method employed by Klebs. In three of these animals which were examined respectively on the 9th of January, the 19th of February, and the 10th of March 1869, I had the opportunity of verifying the perfect accuracy of his description, so far as relates to the distribution of tuberculous granulation on the peritonæal surface of the diaphragm; but I have been unable to trace any indication of the origin of lymphoid corpuscles from epithelial elements.

The results of my investigation of this question are as follows: The arrangement of the lymphatic vessels in the *centrum tendineum* depends upon that of the two tendinous layers of which the aponeurosis consists. Of these layers, the lower, which is the strongest, consists of fibres having the same direction as those muscular fibres of the diaphragm which take their origin from the ribs; so that they converge backwards and towards the middle line. The upper layer, which is much less distinct, has the same general direction as the muscular fibres which are [illegible]d into the posterior edge of the central tendon. The fibres of [illegible]rior layer are divided into bundles by splits or intervals of [illegible]ize to be visible to the naked eye. The lymphatic vessels on

* [illegible]isch, Lehrbuch der pathologischen Gewebelehre, p. 221.

the peritonæal aspect of the aponeurosis present themselves in two forms; (1) Sinuses or lacunæ, which lie immediately underneath the epithelium of the peritonæum, embedded as it were in the basement membrane (*Grundsubstanz* of v. Recklinghausen). (2) Radiating channels which occupy the spaces between the tendons. The lacunæ are of the most various forms; they are scattered very irregularly on the under surface of the central part of the aponeurosis, occupying a space greater than that of the intervals which separate them from each other. (See Plate VIII., Fig. 1.) They communicate by tubular channels so as to form a kind of plexus underneath the epithelium. Both the lacunæ and the channels of communication are lined with an endothelium of great beauty and regularity, consisting of plates which differ from those of the veins and arteries in their larger size and remarkably sinuous outlines, a peculiarity of form which renders it impossible to mistake them for any other epithelial structure in the body. They communicate directly with the deeper layer of intertendinous radiating vessels already mentioned, by which the lymph is conveyed towards the centre of the aponeurosis, there to be discharged into larger lymphatic trunks which, according to Ludwig and Schweigger-Seidel, tend towards the anterior wall of the thorax, and thus find their way to the thoracic duct. It is evident that if Professor Klebs is right in supposing that the tuberculous new growth is either contained in the lymphatic channels, or springs from their walls, the distribution of the diseased product in the tuberculized diaphragm must correspond to the arrangement of lymphatic vessels above described. My investigations afford no support to this supposition. They show (1) that as regards the tissue immediately underneath the epithelium, the arrangement of the nodules or granulations has no relation to the lymphatic lacunæ; and (2) that the radiating intertendinous lymphatics never contain collections of lymph corpuscles. The origin and growth of granulations on the under surface of the diaphragm consist here, as in the rest of the peritonæum, of the multiplication of corpuscles already existing and forming part of the affected tissue. By the examination of numerous healthy diaphragms, I have ascertained that normal adenoid tissue, presenting the usual characters, and differing in no respect from that which constitutes tuberculous granulations, is to be found under both layers of serous membrane, and that it exists in such abundance in the neighbourhood of the superficial veins on the peritonæal surface of the aponeurosis that it forms sheaths to those vessels. These sheaths are so distinct and well marked, that in diaphragms not stained but merely rendered transparent by steeping in glycerine, the course of the veins can be traced as opaque lines when the membrane is examined under a low power; the adventitia of the superficial arteries presents no such peculiarities.

In correspondence with these facts as to the natural adenoid pulp I found that in the animal examined on the 9th of January, all the numerous granulations which existed on the peritonæal surface of the diaphragm were in relation with vessels, and that in the smallest granulations it could be distinctly seen that the new growth sprang not from the adventitia of an artery, but from the adenoid sheath of a vein. From my later dissections it appeared that each granulation eventually projects above the surface of the membrane, first as a rounded elevation, then as a wart or papilla, being finally converted by the flattening of its apex into a round disc attached by the middle of one side to the surface of the membrane; the other side being in contact with the opposed surface of the liver. If other evidence were wanting that the tuberculous new growth does not originate from the walls of the lymphatic

vessels, it might be found in the fact, that although the distribution of those vessels on the upper and under surface of the membrane is so entirely different, the granulations found on the pleural surface were as numerous as those on the peritonæal and had the same arrangement.

Additional Observations as to the Structural Changes observed in the Liver.

The structure of the liver of the guinea-pig resembles very closely that of the rabbit, which has been minutely studied by Hering.* In hardened livers it is easy to demonstrate the arrangement of the intra-lobular capillaries. In sections at right angles to the intra-lobular vein they are seen to converge from all sides to the axis of the lobule. Extremely numerous near the periphery of the acinus, they diminish in number towards the centre, by the repeated confluence of two into one. Consequently all the capillaries tend towards the axis, so that in every section cut longitudinally the direction of the blood stream may be readily determined. Thus the capillaries may be regarded as a framework of radiating cylinders in which the liver substance is contained, filling up the whole of the space not occupied by the vessels; whence it necessarily follows that the liver substance, although in every section parallel to the general direction of the vessels, it looks as if it were divided into separate masses, cannot really be so; and that in reality it must form a network of columns of cells, which, as regards the space it occupies is complementary to that formed by the capillaries. These columns do not (as appears to be the case in the rabbit) consist of single rows of cells; for it is almost always seen, when they are cut across, that at least two cells are divided.

The structure and mode of origin of the bile ducts, from their great importance in relation to morbid changes, require special consideration. In the guinea pig the smallest bile ducts are cylinders $\frac{1}{1100}''$ in diameter, with lumina measuring $\frac{1}{4000}''$. Each consists of a membranous tube enclosing nucleated cells, the nuclei of which are of the same size as those of the liver cells, and closely resemble them. In general these terminal tubes are to be met with only in the inter-lobular spaces; but they can be often seen to penetrate into the peripheral masses of cells. In certain laminar expansions of liver substance which are to be found on the outer surface of the portal lymphatic glands, I have been able to observe that these ducts lined with epithelium sometimes end in cylindrical columns of true liver cells, the arrangement of which, although much less regular than that of the epithelium, shows distinctly that they surround an axial channel. In this case the relation between the epithelial and gland cells corresponds completely to that which holds in reptiles. In these animals the glandular cells form cylindrical columns the constituent elements of which are arranged like epithelium in a regular and symmetrical manner round the axial duct. No such arrangement can be traced in the lobules of the guinea pig's liver, for here the acinous type of structure so predominates over the tubular that the latter is wholly indistinguishable. In the guinea pig the arrangement of the intra-lobular ducts is no doubt the same as in the rabbit, in which Hering has shown that they are minute channels hollowed out, as it were, in the walls of contiguous cells. These channels run in a direction parallel to that of the radiating capillaries, and are connected with each

* Hering, Ueber den Bau der Wirbelthierleber, Sitz.-Berichte der Wiener Akad. d. Wissensch. Bd. liv. p. 336; Schultze's Archiv., Bd. iii. p. 88. See also Eberth, Untersuch. über die Leber der Wirbelthiere, Schultze's Archiv., Bd. iii. p. 423.

other by cross branches of communication, so that the whole assumes (when seen in a longitudinal section) the appearance of a network of oblong spaces; whence it necessarily follows that each bile channel occupies the axis of one of the columns of liver cells already described. The return of the structure to the original tubular type, when no longer compelled to conform to the general acinous plan on which the organ is constructed in the higher animals, will be seen to have an important pathological bearing as indicating that the epithelial and gland cells are in reality homologous structures.

The capillary framework of the acini may be demonstrated in the healthy liver by the method of His. (See Plate III., Figs. 1 and 2.) In examining the capillaries thus exposed, it is seen that in addition to their considerable diameter as compared with capillaries elsewhere, they look as if they were surrounded by a continuous sheathing of apparently homogeneous membrane irregularly scattered with round cells, the nuclei of which are readily stained by carmine. In the human liver the appearance is perfectly similar. The researches of MacGillavry* have shown that this sheath belongs to the lymphatic system. He has found by injection that in the liver, as in the brain, the capillaries are surrounded by lymph channels which in fact are the beginnings of the absorbent system of the gland. Following the capillaries towards the periphery of the lobules, they enter the larger lymphatic channels, which stand to the ducts in a relation similar to that in which the pulmonary lymphatics stand to the bronchi. At the hilus and in the ligamentum-hepatico-duodenale they pass through a number of lymphatic glands, and are no doubt in close relation with the masses of adenoid tissue which, as I have already said, are to be found even in the healthy liver in the portal canals.

As regards the general structural character of the changes which are produced in the liver by the tuberculous infection, I have nothing to add to my former statements. They have been since described by Dr. Petroff and by Dr. Fox, whose accounts agree in all essential respects with my own. The chief change, says Dr. Fox, "is the appearance "of a tissue of a glistening, semi-transparent character, which occupies "the substance of the organ to a variable extent. Sometimes it only occurs "in little specks of the size of a pin's head or a poppy seed; sometimes "it is in larger masses; sometimes it runs in lines, mapping out the "acini very distinctly; sometimes it is found in irregular masses in "which there is no trace of liver structure visible to the naked eye; "or the conditions before described may be reversed, and remains of "natural-looking liver tissue may be seen running in lines irregularly "through the semi-transparent tissue."† The observations of Dr. A. Petroff,‡ although short, are comprehensive and very clearly expressed. He differs from Dr. Fox and myself only in one particular, namely, in stating that although the new growth, as a rule, originates from the inter-lobular spaces, distinct masses of it are sometimes found either around the intra-lobular veins or even in the substance of an acinus, which are not continuous with the larger layers or masses by which the lobules are separated from each other.

There being, therefore, a complete concurrence of observation as to the general features of the process, we are in a position to proceed to

* MacGillavry, Zur Anatomie der Leber, Sitzungsbr. der Wiener Akad. 1864, Bd. l. p. 207.

† Fox, loc. cit. p. 12.

‡ Dr. A. Petroff, Prof. in Kasan, Zur Impfbarkeit der Tuberculose Virch. Archiv. B. xliv. S. 129.

the examination of the other questions which suggested themselves at the close of my last year's inquiry; as, for example,

1. From what normal structure does the cellular reticulum, which at first constitutes the whole of the new growth, originate?

2. What is the ultimate destiny of the diseased parts?

I propose to consider each of these in succession.

Relation of the new Growth to existing Structures.—In the liver, as in the lymphatic glands, different parts of the same organ are always found to be in different stages of alteration. Thus at an early period, as, for example, six weeks after infection, the only changes which can be discovered by the naked eye consist in general enlargement and unnatural paleness of the whole organ, with granulations, masses, or laminæ of transparent material scattered through its substance. But on minute examination, even of the most healthy parts of such a liver, important structural alterations are discovered, both in the acini themselves and in the inter-lobular tissue. In cross sections of the inter-lobular spaces, *e.g.*, sections made near the surface in planes parallel to that of the capsule, it is seen that the inter-lobular vessels and ducts, instead of being in immediate contact with the peripheral ends of the columns, are sheathed in adenoid reticulum. The meshes of this reticulum are in some parts so minute as to contain only single lymph corpuscles (Plate IV., Fig. 4,) while in others they are of various sizes. The larger spaces contain veins or arteries (lymphatics?) and ducts. The smaller enclose masses of lymphoid corpuscles, the position and relations of which may be correctly stated by saying that they and the fine reticulum by which they are held together, fill up all the space not occupied by the vascular structures above mentioned. In pencilled sections these masses are apt to be removed altogether, so that the network which occupies the portal canal appears much coarser than in its original condition. (See Plate VI., Fig. 3.) The portal veins and arteries are unaltered, but it is constantly observed that the ducts, and especially those that are in immediate relation with liver cells, are enlarged, and that their epithelium has lost its regularity of arrangement. From the examination of a great number of similar sections, I infer that in the inter-lobular spaces the disease begins as an overgrowth of the normal adenoid pulp of the portal canals. In the acini the first change observed is a remarkable one. It consists in dilatation of the radiating capillary blood channels and in the appearance of corpuscles in great number within these channels, many of which cannot be distinguished from the colourless corpuscles of the blood, while others differ from them both in size and appearance. They measure from $\frac{1}{4000}''$ to $\frac{1}{1200}''$; the larger are nucleated, the smaller might be described as themselves nuclei. (See Plate III., Fig. 4, and Plate VI., Fig. 4.) Here and there they collect in great numbers, so as to choke up the vessel in which they appear to be contained. They differ mainly in their variability of size from the corpuscles of the reticulum, which seldom exceed $\frac{1}{3000}''$ in diameter. These appearances clearly admit of two interpretations. It may be supposed, either that the bodies in question are in reality what they seem to be, or that they are corpuscles which have originated in the vascular sheath, and have grown into the capillaries. It is not possible to determine by direct observation which of these views is the true one.

As a strong ground for believing that the bodies in question are inside of the capillaries, it is to be borne in mind that the existence of large numbers of colourless corpuscles in the blood vessels leading from adventitious adenoid tissue, is a condition which has been already met with in our study of the omentum; and further, that in all probability the spleen during its first stage of morbid overgrowth delivers

into the portal circulation many more colourless blood corpuscles than in its natural condition. The large size of the corpuscles seems to me to tell as much against the one view as the other; for in this respect they differ as completely from the colourless corpuscles of the blood as from those of the adenoid reticulum. Whatever may be the origin of these bodies, it is certain that their presence must conduce, with other causes to be immediately mentioned, to obstruct the intra-lobular circulation; for it is constantly observed that the vessels in which they are found are either obliterated or plugged with blood discs.

The eventual result of the morbid process is the conversion of the whole organ into a mass of semi-transparent aspect, which resembles both in consistence and structure a lymphatic gland in advanced fibrous degeneration. The steps which lead to this result are as follows:—We have already seen how all the tubular organs in the portal canals lie in a network of transparent intermediary substance continuous with that which forms the adenoid reticulum, and that in an early stage of disease this network becomes coarser and more distinct. It is very difficult to trace this structure into the acini, so long as their condition is unaltered; but in preparations of the kind represented in Plate III., Fig. 1, in which the intra-lobular vascular network is freed from the liver cells by pencilling, I have always found that bands or strings of hyaline substance bridge over the interspaces between the capillaries at distances which evidently correspond to the width of the liver cells; so that from my own observation I am inclined to concur with those who believe that the organ is pervaded throughout by a framework of hyaline bands, which has the same relation both to the capillaries and to the cellular elements of the organ as that which exists between the corresponding structures in the lymphatic glands. Whatever conclusion we may arrive at as to the presence of the so-called *tela conjunctiva* in the healthy organ, there is no doubt that as soon as the tissue of a lobule becomes affected by tuberculous disease, the existence of such a framework becomes obvious; and that the first change by which the encroachment of the inter-lobular new growth of the glandular tissue is indicated consists in the development of transparent bands or threads, in the interlacing of which the capillaries and liver cells gradually become involved. The arrangement of these bands is such, that in proportion as they become thicker and stronger the affected tissue is converted into a fibrous looking meshwork, in the holes of which the original elements are imprisoned. In this way the liver cells become broken up into masses which are separated from each other by septa of transparent material. Hence two results follow—on the one hand the capillaries collapse and lose themselves in the trabeculæ of the newly formed stroma, while on the other the liver cells, which at first struggle for existence with adventitious cellular elements in the loculi of the stroma, finally waste away, the nucleus often remaining after the body of the cell has disappeared.

Simultaneously with this change the terminal bile ducts become the seat of another and most remarkable alteration. In all specimens in which the diseased process is far advanced, certain spots are to be observed in the sections which are distinguished by their extreme transparency, not merely from those parts in which the liver cells are still in situ, but from the general mass of diseased tissue of which they form a part. The transparency of these spots is found to be due to the fact that the loculi, instead of containing liver cells or the remains of their disintegration, are occupied by bile-duct epithelium. In comparing them with sections of normal bile ducts it is found that the form and measurement of the cells are identical, and that they differ in nothing excepting the irregular

size and contour of the loculi themselves, and the absence of any arrangement in their contents. The only other view which can be entertained of their nature is that they are liver cells which have lost their granular contents, retaining their nuclei; in favour of which it is to be noticed that loculi are often to be found which are partly filled with liver cells and partly with epithelial cells. (See Plate III., Fig. 3.)

The final stage of the process is easily described. All cellular elements disappear excepting a few scattered lymph corpuscles. What remains is a fibrous network in the arrangement of which that of the tissue which it has supplanted may still be traced. In other respects it resembles the corresponding structures which we have already studied in the spleen and lymphatic glands (Plate VI., Fig. 4). Thus it appears that the adventitious adenoid pulp of the liver is liable to a process of fibroid degeneration which corresponds in all its important features to that which affects the natural tissue in those organs of which it forms the essential constituent.

Additional Observations as to Tuberculosis of the Lungs.

In the lungs the lesions are so uniform in their character in all the animals I have examined that I have nothing to add to the general description given last year, and shall confine myself to those questions which were then left undecided, and to others which arise out of observations made since. These refer to the relations of the adventitious masses of adenoid pulp which were designated in my last report peribronchial granulations, with those which exist normally in the lung, as well as to the irongrey nodules.

Considering that these granulations occupy the same position and have the same structure as the normal ones, differing from them only in size, it is natural to conclude that the relation between diseased and healthy structure is the same in the lungs as we have already found it to be in the peritonæum. As to the significance of the semi-transparent nodules which have been so often compared to miliary tubercles, repeated observations have shown me that the structure represented in my fourth figure (see former Report) is uniformly met with in microscopical sections of these bodies; and that in fact the semi-transparent nodules are not so analogous to miliary tubercles as to blocks of lobular catarrhal pneumonia. They owe their transparency not to the structural elements of tubercle, but to cells identical in size and appearance with the natural alveolar cells of the lung. In order to understand the nature of the pathological process of which these nodules are the expression, the manifestations of disease must be studied separately in each element of the original tissue, *i.e.*, in the alveolar cells, the alveolar and bronchial epithelium, the blood vessels and lymphatics.

The alveolar cells are nucleated bodies which are always to be found in the alveolar cavities of the healthy lung. Each probably consists of a solid envelope of transparent substance collected round a more refractive central part. They usually contain a good many granules of black pigment, which are embedded in the envelope along with other granules of different chemical constitution. When seen in the healthy injected lung they look as if they filled the spaces between the network of capillaries which covers the internal surface of each alveolus. This arrangement, although it is, I believe, quite accidental, has led to their being often described as epithelium, in consequence of which much confusion has been introduced into the subject. The true alveolar epithelium is very difficult to demonstrate. Its elements are much smaller than those

above described, and correspond in structure and arrangement with those of the terminal bronchial tubes. The latter can be readily studied in sections recently prepared by v. Recklinghausen's method. In such sections the epithelium may either be examined *in situ*, or may be prepared separately. It consists of oval or oblong plates (Plate V., Fig. 4), each of which contains a spherical nucleus about half as wide as itself. As the epithelium nuclei are readily stained by neutral solution of carmine, the bronchial epithelium, when so stained resembles a collection of lymph corpuscles, and when seen in double layer may be easily mistaken for a granulation, for which reason carmine staining is rather a hindrance than a help in studying diseased lungs. On tracing this terminal epithelium into the lobule into which the bronchiole leads, it is seen to fade away gradually till it becomes imperceptible, the reason apparently being that it is so exceedingly delicate that it is destroyed by any of the ordinary liquids used under the microscope. That the epithelium really does extend into the alveoli themselves without materially changing its form, has I think been satisfactorily demonstrated by Chrzonszczewsky.*

In the alveolar walls of the healthy uninjected lung no structure can be distinguished excepting the delicate elastic framework of fibres by which the septa are supported. But in the diseased parts these septa are thickened in a way which I described last year as analogous to the thickening of the trabeculæ of the spleen and lymphatic glands by the interstitial growth of nucleated cells. That the irongrey nodules do not consist entirely of alveolar cells may be readily proved by applying the process of pencilling to microscopical sections made parallel to the surface. By this means all the alveolar cells may be worked out, while the parietal cells are retained in their place by the connective substance of the septum in which they originate and are embedded.

In animals killed at an early stage of tuberculosis, that is to say, about four weeks after inoculation with tuberculous matter, no change is observed excepting that the peribronchial adenoid pulp is increased, or in other words, that true miliary granulations are formed in the neighbourhood of the terminal bronchioles. This fact appears to afford the key to the mode in which the irongrey nodules are produced. Whether the choking up of the air cells is a merely mechanical result of the accumulation of adventitious matter around the bronchioles or of a catarrhal process, there can, I think, be little doubt that the granulation stands to the block of lobular pneumonia in the relation of cause to effect, and that when a kernel of adenoid pulp occupies the centre of a nodule the fact signifies that the nodule originated from it.

We have, lastly, to consider the relation of the process to the absorbent vessels. It has been long known that the lymphatics of the lungs may be divided into a superficial and a deep system of vessels. In the dog† the superficial lymphatics spread over the whole surface of the organ in the form of a network, the vessels following the divisions between the lobules. From this network the lymph finds its way, by vessels which sink into the depth of the lung along with veins, and then accompany the bronchial tubes to their origin. In this course the lymphatics form more or less perfect sheaths around the blood vessels and bronchi. When the lymphatics of the lung are injected

* Chrzonszczewsky, Ueber das Epithel. der Lungenbläschen der Säugethiere, Würzburger Med. Ztscht. Bd. iv. p. 206.

† Wywodzoff, Die Lymphwege der Lunge, Wiener Med. Jahrbücher, Bd. xi. p. 1, 1866.

in the dog the mass may be traced even into the septa of the alveoli. From the alveoli the lymphatic channels converge so as to form larger vessels, which commence in the immediate neighbourhood of the bronchioles and terminal arterioles. At these points of confluence, says Wywodzoff, collections of lymph corpuscles are always to be found, which he supposes to be contained within the lymphatic cavity. However this may be, the fact is of great interest as showing the close relation between these masses and the absorbents. The observations of Wywodzoff relate entirely to the pulmonary lymphatic system of the dog. It has been shown by Afonassiew,* that if carmine is injected into the pleura of the living guinea-pig, the liquid finds its way into the deep lymphatics which accompany and surround the lymphatic tubes, the course of which is indicated by the staining of the tissue; so that there is every reason to believe that the superficial system of absorbents communicates with the deep system in the same way in the rodents as in the dog.

CONCLUSIONS.

1. The characteristic product of tuberculosis is not an aggregation of shrivelled particles of irregular form, but a tissue composed of lymph corpuscles held together by a network of hyaline connective substance.

2. There is a close structural analogy between this tissue and that of certain follicular organs belonging to the lymphatic system, *e.g.*, the follicles of Peyer, the ampullæ of the lymphatic glands, &c.

3. All the favourite seats of tubercle are naturally characterized by the presence of this tissue, which, from the analogy stated above, may properly be called *adenoid.*†

4. The natural distribution of adenoid tissue in the body is in intimate relation with the lymphatic system. In the great serous membranes (which v. Recklinghausen's discoveries have taught us to regard as walls of lymphatic reservoirs) it forms sheaths round the blood-vessels, or masses of microscopical dimensions and irregular contour underneath the epithelium. In the solid viscera it is distributed here and there in the course of the lymphatic channels.

5. In the peritonæum, tuberculosis primarily consists in the enlargement or overgrowth of these sheaths or microscopical masses of adenoid tissue, and consequently the tuberculous nodules which are formed have the same intimate structure, and stand in the same anatomical relation to the vessels and epithelium. In the viscera the essential lesions also consist, not in new growth, but in overgrowth of pre-existing masses of adenoid tissue.

6. The primary local lesion in artificial tuberculosis, whether the cause be simple wound or specific inoculation, consists in the development at the seat of injury of granulations or nodules which have similar structural characters with those of adenoid tissue elsewhere, but cannot as yet be shown to be in relation with the absorbent vessels.

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* Afonassiew, Ueber den Anfang der Lymphgefässe in den serösen Häuten, Virch. Arch. Bd. xliv. p. 37.

† The term adenoid has been introduced into pathological nomenclature in an entirely different sense. It has been applied to tumours which consist essentially in overgrowth of elements belonging not to adenoid, but to acinous glands, *e.g.*, of the epithelium of the liver and breast respectively.

7. The first step in the dissemination of tubercle, consists in its being absorbed primarily by the lymphatics (which convey it to the lymphatic glands of which they are tributaries), and secondarily by the veins. Having thus entered the systemic circulation, it is distributed universally by the arteries. The serous membranes seem, however, by preference to appropriate it, and from them it extends by contiguity to the superficial parts of the organs which they cover.

8. The final stage of the process consists in the tertiary infection of the glands of each diseased organ, which glands consequently undergo enlargement and induration, and eventually become partially caseous. The enlargement is due to the multiplication of cells in all the tissues of the organ, but more particularly in the alveoli—the hardening to a process of fibrous degeneration—while the caseation consists in slow necrosis of the previously hardened and anæmic parts. From the first the gland is incapable of performing its functions, but it is not until induration commences that the absorbents of the organ to which it belongs are completely obstructed.

9. In the liver of the guinea-pig, and in some other organs, tuberculous tissue undergoes a fibroid degeneration and caseation, the results of which cannot be distinguished from those observed in the normal adenoid tissue of the lymphatic glands and of the spleen.

10. As regards the question of a specific contagium of tubercle, we think it very important to note that this is not as yet disproved by the facts of traumatic tuberculosis. It still remains open to inquiry whether or not injuries which are of such a nature that air is completely excluded from contact with the injured part are capable of originating a tuberculous process. The results of the following experiments undertaken at the instance of Mr. Simon, with special reference to this question, seem indeed to suggest that they may not be so. Setons steeped in carbolic acid were inserted in 10 guinea-pigs on the 24th of September 1868, each animal receiving two. At the same time extensive fractures of both scapulæ were produced on five others, care being taken not to injure the integuments. No tuberculosis or other disease of internal organs resulted in either case. These facts certainly point to the necessity of further investigation in this direction.

Explanation of Plate I.*

Fig. 1. A knot of capillaries from the peritonæum in the neighbourhood of the pancreas. *a.* Arteriole. *b.* Vein. *c.* Mass of lymph corpuscles in which the capillaries are embedded. *d.* Network of omentum. From a healthy guinea-pig; the vessels have been filled with carmine by Chrzonszczewsky's method. Magnified 460 diam.

Fig. 2. An artery partly surrounded by a vascular, adenoid sheath; from the same preparation as Fig. 1. The large connective tissue corpuscles (*a.a.*) stained with carmine differ from lymph corpuscles principally in size. They present the appearance of round or oval masses in which neither granules nor nuclei can be discovered. Magnified 650 diam.

Fig. 3. A vein and artery from the same preparation. The vein is filled with colourless blood corpuscles or lymph corpuscles, some of which are stained, while others remain of their natural colour. Magnified 650 diam.

Fig. 4. Mass of adenoid tissue surrounding capillary loop; the smaller vessel can be traced directly from an artery, the larger opens into a vein. Magnified 460 diam.

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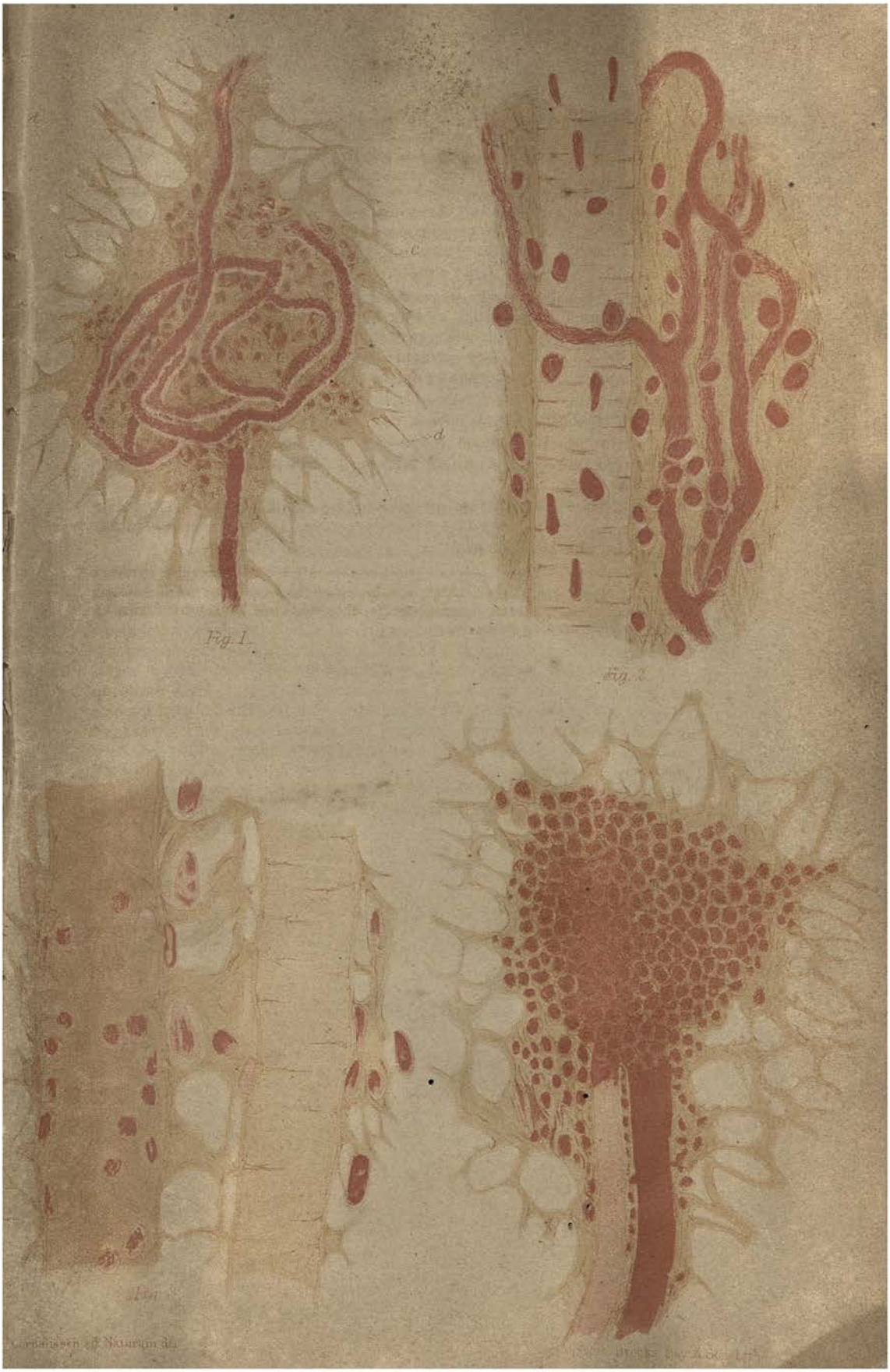
* All the figures on Plates I.—VII. were drawn by the artist from the microscope, with the aid of the "neutral tint reflector." Those on Plate VIII. were drawn by myself with the drawing prism.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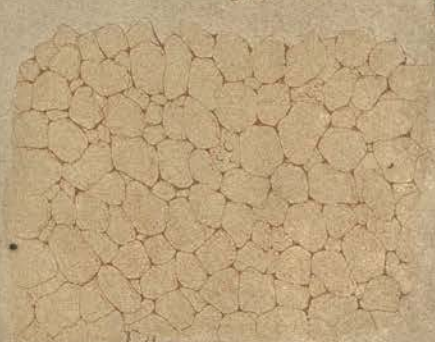

Fig. 5.

Explanation of Plate II.

Fig. 1. Part of a vascular anastomosis from the peritonæal fold enclosing the pancreas, from a tuberculized guinea pig. The drawing shows the relation between the tuberculous nodules and the larger vessels of the peritonæum. The vessels occupy the axis of a cylindrical sheath in which two kinds of tissue can be distinguished, viz.: an adenoid layer externally and fat cells internally. The nodules, which are of extreme transparency, are outgrowths from the adenoid part of the sheath. *a.a.* Nodules. *b.* Peritonæal membrane. Magnified 7 diam.

Fig. 2. Part of vascular sheath from the same preparation magnified 100 diam. *a.* External adenoid layer. *b.* Internal adipose tissue.

Fig. 3. Aggregation of lymphoid corpuscles underneath the peritonæal epithelium in a healthy animal. *a.a.* Network of omentum. *b.* Nuclei of epithelium. Magnified 650 diam.

Fig. 4. Epithelium of healthy omentum, prepared by v. Recklinghausen's method. *a.a.* Epithelium covering an artery and vein. *b.b.* Epithelium covering the adenoid sheath. At *c.* the epithelium is deficient. Magnified 650 diam.

Fig. 5. Epithelium covering a tuberculous nodule. Magnified 650 diam.

Explanation of Plate III.

Fig. 1. Tela conjunctiva of the human liver. *a.* Granulation of adenoid tissue. *b.b.* Nuclei embedded in the sheaths of the capillaries. *c.c.* Liver cells, most of which have been removed from the framework by pencilling. (From a case of general lymphoma communicated to the Pathological Society by Dr. Murchison). Magnified 460 diam.

Fig. 2. Reticulum of liver of guinea-pig in early stage of tuberculosis. *b.* and *c.* as in Fig. 1, magnified 460 diam. The two drawings are intended to illustrate the mode in which overgrowth of lymph corpuscles commences in the sheaths of the capillaries of the acini, which sheaths collectively constitute what is called the tela conjunctiva. They further show the anatomical correspondence between lymphoma and tuberculosis.

Fig. 3. Liver of guinea-pig, No. 56, (2d series). *a.* Vascular spaces containing lymph corpuscles and coloured blood corpuscles. *b.* Liver cells. *c.* Reticulum. *d.* Nuclei of epithelium contained in dilated bile ducts. Magnified 460 diam.

Fig. 4. Section of the same liver in an earlier stage of alteration. *a.* Vascular spaces. Many of the lymph corpuscles are of large size and nucleated. *b.* Liver cells. Magnified 460 diam.

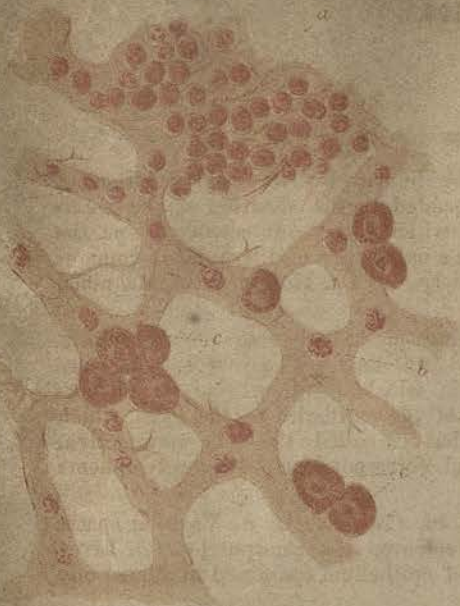

Fig. 1.

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Fig. 7.

Explanation of Plate IV.

Fig. 1. A medullary cylinder of a healthy lymphatic gland. *a* Cylinder of adenoid tissue in the meshes of which numerous lymph corpuscles are embedded. *b*. Coarser network of lymph sinus from which the lymph corpuscles have been removed by pencilling. Magnified 650 diam.

Fig. 2. Summit or extremity of an ampulla. *a*. Reticulum of the ampulla. *b*. Limiting membrane of the ampulla, the structure of which differs from that of the reticulum only in the closeness of the filaments of which it consists. *c*. The lymph space. *d*. Fibrous connective tissue which forms the cortical substance of the gland. With the exception of the few lymph corpuscles shown, all have been removed by pencilling. Magnified 460 diam.

Fig. 3. Portion of the same ampulla. The figure is intended to show the relation between the reticulum and the vessels. *a*. Artery, the structure of which is seen indistinctly through the sheath of closely woven connective tissue which covers it. *b.b*. Limiting membrane of the ampulla, the structure of which is continuous with that of the sheath of the artery. *c.c*. Reticulum of the ampulla, from the meshes of which the lymph cells have been pencilled out. *d.d*. Capillaries, the sheaths of which are united with the filaments of the reticulum. Magnified 460 diam.

Fig. 4. Reticulum adjoining an interlobular bile duct from which the lymph corpuscules have been removed by pencilling. The meshes of the reticulum are oval, their long axes being in the same direction as the bile duct and the vessels accompanying it. Magnified 460 diam.

Fig. 5. Cross section of four bile ducts, surrounded with adenoid tissue, from the reticulum of which almost all the lymph corpuscles have been pencilled out. *a.a*. Bile duct epithelium. *b*. Reticulum. Magnified 460 diam.

Fig. 6. Adenoid tissue in the neighbourhood of a minute branch of the hepatic artery. (From a liver in advanced fibroid degeneration in which the hepatic artery has been injected.)—The reticulum is transformed into a sponge-like tissue in which laminæ take the place of filaments. Lymph corpuscles, many of which are nucleated occupy some of the loculi. Magnified 460 diam.

Fig. 7. Lymph corpuscles from blood of portal vein of guinea-pig, No. 56, (2d series). Magnified 460 diam.

Explanation of Plate V.

Fig 1. Nodular tubercular overgrowth of adenoid vascular sheath from the omentum of a tuberculized guinea-pig, killed four months after inoculation. The abdominal organs have been injected with Beale's blue, by the cœliac axis. The preparation demonstrates the extreme vascularity of tuberculous new growth. The capillaries of new adenoid tissue being of great delicacy, they cannot be made out without injection. In the present instance the injection had passed into the veins, many of which were slightly coloured. Magnified 460 diam.

Fig. 2. Section of a pulmonary lobe of a healthy guinea-pig procured for the purpose of demonstrating that adenoid tissue, indistinguishable from that which constitutes tubercular granulations, exists in the normal lung. The section has been made so as to cut across the principal artery and bronchus of the lobe. *a*, artery ; *b*, bronchus—the brownish red bodies being imperfect cartilaginous rings ; *c*, mass of adenoid tissue surrounded by a layer of black pigment. This mass is cylindrical, the axis of the cylinder being parallel to that of the bronchus and artery, to which structures its relative position is always as represented ; *d*, alveolar tissue ; *e*, loose connective tissue surrounding the artery and bronchus. Magnified 60 diam.

Fig. 3. Apparently healthy lung of guinea-pig, No. 94, (2d series) inoculated three weeks previously by introducing tuberculous material into the peritonæum. The lung was first injected with Prussian blue by the pulmonary artery, and then filled to distension with warm solution of gelatine. In fresh sections stained with carmine of the lung solidified in this way, microscopical collections of lymph corpuscles (*a*) could be discovered here and there, all of which were in close proximity to small arteries or bronchioles. In the drawing a "granulation" of this kind is seen lying behind a minute arterial trunk which the knife has happened to truncate immediately in front of the centre of the little mass. Its rounded form is evidently due to its having grown into an alveolar cavity, the capillaries of which may be traced over it. The rich capillary network (*b*) which surrounds it belongs to other adjoining alveoli. Magnified 200 diam.

Fig. 4. Shred of epithelium from an infundibulum, stained with nitrate of silver. This epithelium does not cease abruptly where the internal surface of the infundibulum becomes continuous with that of the alveoli, but gradually loses its distinctness. I have failed in my endeavours to demonstrate an epithelial layer in the alveoli, but do not doubt its existence. Magnified 650 diam.

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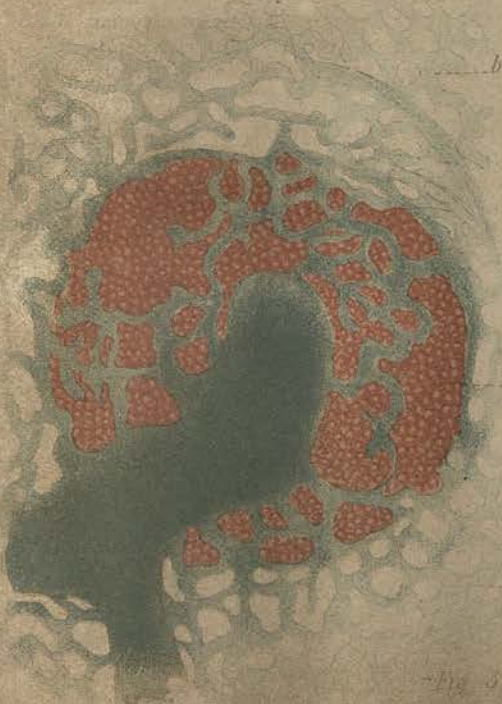
Fig. 2



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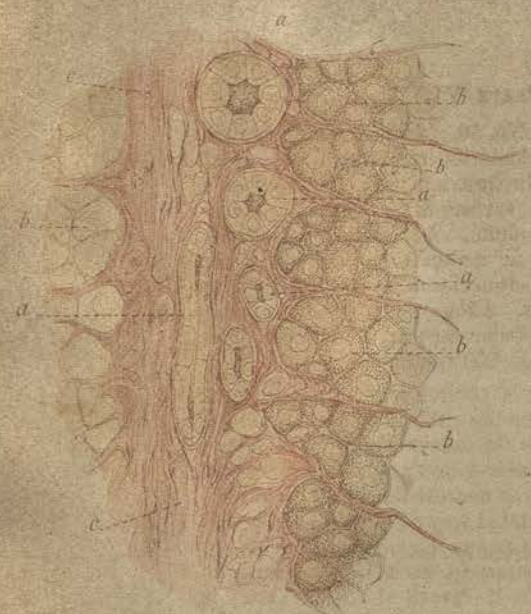

Fig. 1

Fig. 2

Fig. 3

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Explanation of Plate VI.

Fig. 1. Section of liver of guinea-pig, No. 56, (2d series), inoculated 29 weeks before death with transparent material from the supra renal capsule of a patient who had died on the previous day of Addison's disease. The section is vertical to the surface of the organ. *a.a.a.* Interlobular bile ducts lined with epithelium. *b.b.* Ends of the converging columns of liver cells of which an acinus is formed. *c.* Reticulum from the meshes of which the corpuscles originally occupying them have been removed by pencilling. From the obliquity of the plane of section in relation to the interlobular septum, some parts of it appear fibrous, others alveolar. Magnified 460 times.

Fig. 2. Epithelium of the double layer of peritonæum which encloses the extremity of the pancreas of the guinea-pig; the drawing is intended to show the structure of this membrane, in relation to the frequency with which it becomes the seat of tubercular granulation. *a.* Nuclei of the epithelium, some belonging to the layer nearest the observer others to the layer opposed to it. The reticulated wavy lines represent the interstitial cement by which the contiguous elements (scales) are united to each other. Those which intersect each other belong to different layers. The epithelium where it covers the vein (*v.v.*) is modified in form, the scales being oval or oblong. *b.* Apertures in the membrane at the edges of which the two layers of epithelium are continuous with each other. Everywhere else the space between the two layers is occupied either by vessels or by a meshwork of extremely delicate connective tissue fibres, which are continuous with the similar tissue which forms the sheaths of the blood-vessels. This tissue is of such tenuity that even in preparations stained with carmine, it is not distinguishable, unless the epithelium has been removed by previous maceration. The lymphoid corpuscles which exist in such numbers in certain parts of the same membrane are embedded and originate in this structure.

Fig. 3. Section of liver of guinea-pig inoculated four months previously by Dr. Fox with human tubercle. The section is parallel and near to the surface of the organ. *a.* Portal vein and tributaries thereto. *b.* Section of an interlobular duct. *c.* Reticulum occupying the greater part of the portal canal. *d.* Cavity containing remains of epithelium. As in fig. 1, the cells which originally filled the holes of the reticulum have been removed by pencilling. Some have contained adenoid pulp, others liver cells (*e.*) Magnified 460 times.

Fig. 4. Pencilled section of acinous tissue of liver in advanced fibroid degeneration. The reticulum is so abundant, that it seems to constitute the whole substance of the organ. The liver cells as well as the adenoid pulp have entirely disappeared; of the cellular forms that remain some probably are epithelial nuclei, others which appear to be contained in vascular cavities, are I believe of the same nature as the corpuscles met with in the earlier stages of the process in the capillaries. Magnified 460 times.

Explanation of Plate VII.

Fig. 1. Vertical section of capsule of spleen of guinea-pig, No. 56 (2nd series). *a.* External surface of capsule, the epithelium being removed in making the section. *b.* Commencement of a splenic trabecula. *c.* Adenoid tissue forming a sub-peritonæal granulation, the structure of which is continuous with and indistinguishable from that of the capsule of the organ. *d.* Section of a vein. The margin at *e.* corresponds to the position originally occupied by a malpighian follicle, the structure of which can no longer be distinguished. A line connecting the two asterisks would correspond to the natural direction of the capsule. All that lies to the right of it may be regarded as new growth. Magnified 460 diam.

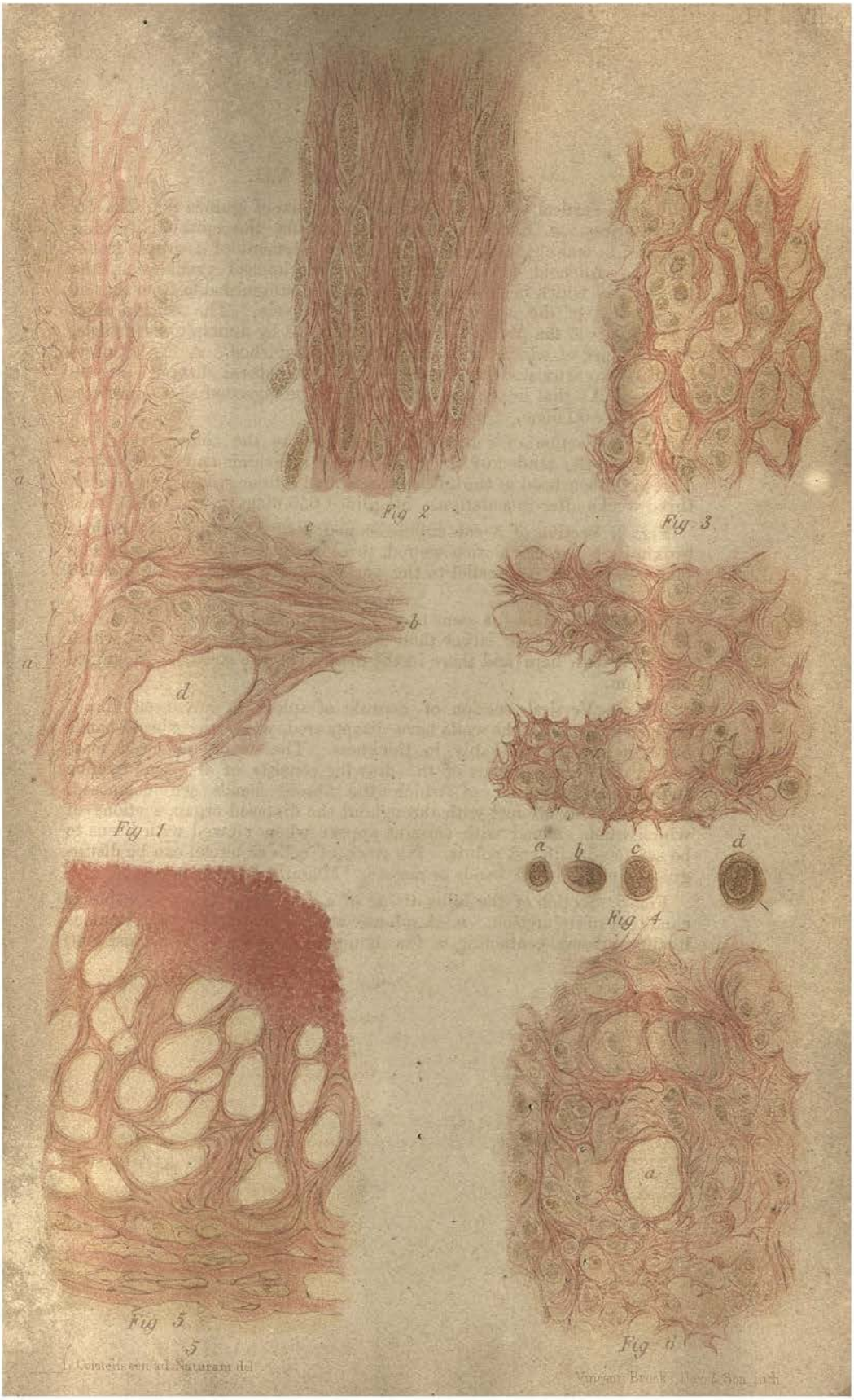
Fig. 2. Section of a new growth occupying the connective tissue adjacent to the tendon of the transversalis abdominis and in the immediate neighbourhood of the inoculation wound; from guinea-pig, No. 94, three weeks after inoculation. Magnified 650 diam.

Fig. 3. Section of a sub-cutaneous nodule of adenoid tissue in close proximity to the inoculation wound, three weeks after inoculation. The plane of section is parallel to the surface of the skin. Magnified 460 diam.

Fig 4. Section of the same nodule in the opposite direction. *a. b. c. d.* Nucleated cells much larger than the ordinary lymph corpuscles, which are met with here and there in the meshes of the stroma. Magnified 460 diam.

Fig. 5. Vertical section of capsule of spleen in advanced fibroid degeneration. All the cells have disappeared, while the fibroid bands have increased remarkably in thickness. The deeply coloured mass shown in the upper part of the drawing consists of the same hyaline structureless material of which the fibroid bands are composed. Similar masses are met with throughout the diseased organ, sections of which when stained with carmine appear when viewed with a lens to be scattered with red points. No trace of cells or nuclei can be distinguished either in the bands or masses. Magnified 460 diam.

Fig. 6. Section of the hilus tissue of a lymphatic gland in a similar condition of induration. *a.* A minute artery surrounded by a loculous hyaline stroma, containing a few lymph corpuscles. Magnified 460 diam.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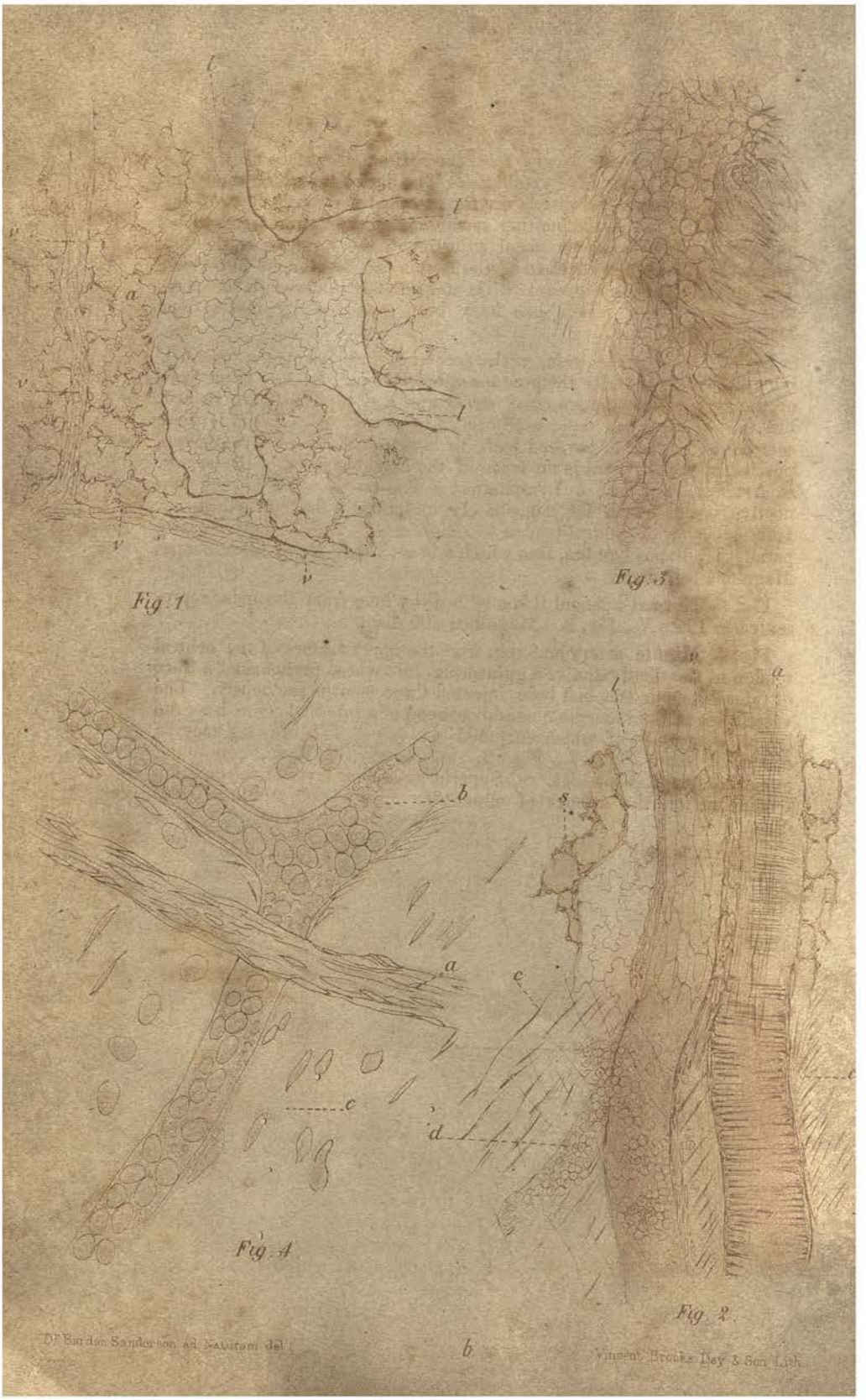
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Fig. 1
Fig. 3
v
a
l
b
s
a
c
c
d
c
Fig. 4
Fig. 2
Dr Burdon Sanderson ad Naturam del.
b
Vincent Brooks Day & Son Lith.

Explanation of Plate VIII.

Fig. 1. A lymphatic lacuna from the peritonæal surface of the diaphragm. *v.v.* Veins. *l.l.* Lymphatics. The dark lines which ramify in the spaces between the vessels are the so-called sap canals of v. Recklinghausen. Near *a*, the limiting membrane of the lacuna seems to be imperfect. By altering the focal adjustment, the layer of epithelium which covers the deep surface of the lacuna can be brought into view. The superficial layer appears to lie immediately underneath the peritonæal epithelium, which has here been removed by maceration. Magnified 207 diam.

Fig. 2. Artery and vein, with accompanying lymphatic channel, lying immediately under the peritonæal epithelium. In the upper part of the preparation, the vascular structures, and sap canals are stained, but the staining has accidentally failed in the lower part. It is there seen that the vein is covered with an interrupted layer of lymph corpuscles, of which there is no trace in the neighbourhood of the artery. *a.* Artery. *v.* Vein. *l.* Lymphatic. *s.* Sap canals. *f.* Fibres of connective tissue which lie immediately underneath the epithelium. *c.* Inferior layer of central tendon of diaphragm. *d.* Split between two parallel tendinous bundles, into which a branch from the vein penetrates. Magnified 207 diam.

Fig. 3. Normal adenoid tissue of healthy lung from the mass represented in Plate V., Fig. 2. Magnified 490 diam.

Fig. 4. Minute artery and vein from the upper surface of the central tendon of the diaphragm of a guinea-pig, into whose peritonæum a trace of tuberculous matter had been injected three months previously. The vessels are in the immediate neighbourhood of a tuberculous nodule, the lymph corpuscles of which surround the vein. This drawing may be compared with Plate I., Fig. 3. *a.* Artery. *b.* Vein, containing numerous lymph corpuscles. *c.* Superior tendinous layer of the centrum tendineum, on the surface of which the vessels lie. Magnified 490 diam.

APPENDIX.

No. 6. *On Chemical Identification of Disease, by Dr. Thudichum.*

No. 6.—FURTHER REPORT, by DR. THUDICHUM, on RESEARCHES intended to promote an improved CHEMICAL IDENTIFICATION of DISEASE.

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A.—*Notes on the Febrile and some other Morbid Processes with reference to their Chemical Investigation.*

Phenomena of the febrile condition.

The febrile condition is constantly associated with the following abnormal phenomena:—(*a.*) Increased temperature of the body. (*b.*) Increased disintegration of albuminous substances. (*c.*) Diminished muscular power. (*d.*) Diminished ingestion of nutriment. (*e.*) Diminished urinary water (*f.*) Diminished powers of the senses and of the sensorium. These changes are common to all febrile states, no matter what may be their specific origin. I proceed to consider the two first conditions only, with the assistance of such chemical information as it has hitherto been possible to gather.

Temperatures in disease.

44, nerve affections.

43·37 in dying.

41·87, agony.

41·75, or death line.

41·62.

41·25 as morning T. always fatal.

50 per cent. line.

Temperatures up to C. 44° occur in certain spinal injuries and in acute tetanus. Next in order are temperatures which occur only during the process of dying, 43·37° being the absolute maximum of T. (T. = temperature) in fatal cases of typhus. At 41·87 begins the agony of death. The line 41·75 is momentous, because hitherto no patient with typhus, whose T. has risen above that line, has been known to recover. I have therefore termed this line the death-line. Patients with shivering fits in the morning may rise to 41·62 and not necessarily die; but when typhus patients reach the temperature of 41·25 in the morning they always die. The line at 41·12 may be termed the 50 per cent. death-line, because one half of all patients going above this line die. From 41° to 40·37 range the average maxima of favourable cases, and from 40°·6 to 40° the average maxima of morning temperatures of the same class of cases, more particularly of typhus fever. At 38·6 we

come to the maximum of health, at 37·6 to the mean, at 36·76 to the minimum of health. At 36·5 we find certain cases of autumnal diarrhœa, simulating typhus and typhoid fever. This is also the death-line of cholera. All cases whose temperature ranges persistently below this line have, as far as the observations of the epidemic of 1866 went, died. The range of the minima of cholera cases is between 36·4 and 33·9, and the lowest T. observed in any case of cholera is 32·9. See tables in 9th Report, particularly Table 40.)

Morning T. of favourable cases.

36·5 is the minimum dead line of cholera.

Lowest T. observed in cholera.

In febrile and other diseases where there is no obstruction to any very great part of the circulation, the most accurate measurements are most quickly obtained in the cavities, rectum and vagina; but the same results are obtained in the axilla, if the thermometer be allowed to remain there until stationary. In some conditions, however, namely in collapse of acute cholera and in the agony of death, the temperatures of the cavities are above the temperatures of the axilla :—*i.e.*, the heat produced in the deeper tissues accumulates in them, not being carried away again by flowing blood, but having to find its way slowly through badly conducting materials. For the same reason the temperature of a body which has just died sometimes rises by several tenths or even an entire degree for some minutes, until the chemical effect of the stored oxygen is exhausted ; when, with the venous condition of the capillary blood, the local death of the tissues takes place.

Difference of T. in axilla and internal cavities.

T. rises immediately after death.

The sensation of cold in the shivering fits of high fever is a deception of the peripheral sense of temperature, produced by the contraction of the small blood vessels of the skin, and the contractile tissues of that organ in general. From the moment that this spasmodic effect ceases the fever patients have the sensation of excessive heat. Their sense of temperature is constantly excited until in delirium they fancy themselves on fire. One of the effects of this condition is that the heart makes increased efforts to circulate blood so as to obtain a compensating reduction of the temperature by increased evaporation from the lungs and skin. The number of the beats of the heart are always greatly increased in fever ; and with this increased labour the heart tends to become exhausted. A kind of artificial fever can be produced by the Turkish bath, especially with its higher temperatures. First there is sweating, then the pulse becomes rapid, and with arterial murmurs and a pulse of 140° per minute, and a rise of the temperature of the body by one or two degrees as measured in the cavities, begins a state of unconsciousness or anæsthesia, which differs entirely from syncope, with which it has been confounded, and is similar to the unconscious conditions of typhus and typhoid and other febrile patients. During this process of the production of anæsthesia by heat the powers of the muscular system are constantly decreasing, until a degree of debility equal to that of the acme of typhus is reached. Very evident in healthy persons, this effect is still more striking in persons suffering from some sorts of paralysis, with but a small amount of contractility in their muscular system left.

Nature of shivering fit.

Artificial fever by Turkish bath.

Increased disintegration of albuminous substance is the second main effect of the febrile process. Its existence and amount are ascertained by comparative analysis of the urine. It is not maintained that the non-nitrogenous matters contained in and introduced into the body during fever are not also disintegrated more rapidly. On the contrary, this is very probably the case with all, such as fat, starch, and sugar, and certainly the case with alcohol, as I have shown in the special chapter relating to that body. See last Report, p. 282. It is also certain that the quantity of non-albuminous matters disintegrated or oxydised influences the quantity of albuminous matters oxydised in the same

Increased disintegration of albuminous matters.

time, by diminishing it; that heat, febrile or normal, may be produced by the oxydation of either, but is produced if possible first from non-nitrogenous matters, and if these are absent or insufficient, then from nitrogenous matters.

Apparatus for collecting excretions.

Respiration apparatus.

In order to the accurate measurement of these effects of the febrile process the food and excretions have carefully to be ascertained and analysed; and among excretions I of course include the products of respiration. The urine has to be collected separately and completely as yielding one of the main and most important indications. In regard of persons who are not bedridden this is best done by means of special apparatus such as I described in 1864, in the Journal of the Society of Arts. And besides food and excreta, the body-weight of the patient has to be taken into consideration during the whole of the disease. All these desiderata can only be observed by the aid of particular arrangements in hospitals, and by the aid of the large and expensive apparatus first constructed at Munich by Pettenkofer and Voit. Where these facilities do not exist the research has to be limited to the determination of the disintegration of the albuminous substances. This has hitherto mainly been effected by the quantitative determination of the excreted urea, by means of Liebig's volumetrical analysis. Now although this gives the main bulk of the products of disintegration, it does not indicate the whole by several per cent. Some inquirers have therefore determined the excreted nitrogen as such, by means of particular processes (Davy, Neubauer). But my researches on uromelanine, omicholine, omicholic acid, have shown that chlorine, which was relied upon as a decomposing agent in the analyses of Davy and others, does not decompose the products just mentioned in such a manner as to liberate their nitrogen, and that in short nothing but actual combustion with soda lime will set all the nitrogen of urine free in the form of ammonia. Liebig's analysis comes, however, closer up to the actual amount than the chlorine process, because urochrome is precipitated by the nitrate of protoxyde of mercury. As this amount of a compound, the nature of which is at present only partly known, enters the account as tetra mercuric-urea-nitrate, it introduces a source of inaccuracy for the elimination of which the future will have to provide. A similar remark holds good with regard to creatinine, uric and hippuric acid. But these it is possible to determine, although by difficult or circumstantial methods only. The indications of the quantity of urea or nitrogen in the urine are of course the more important the more of it is derived from tissue juice and not from daily food; for this proportion assigns the degree in which we get one of the most common results of fever, namely emaciation.

Liebig's, Davy's, and other analyses for urea.

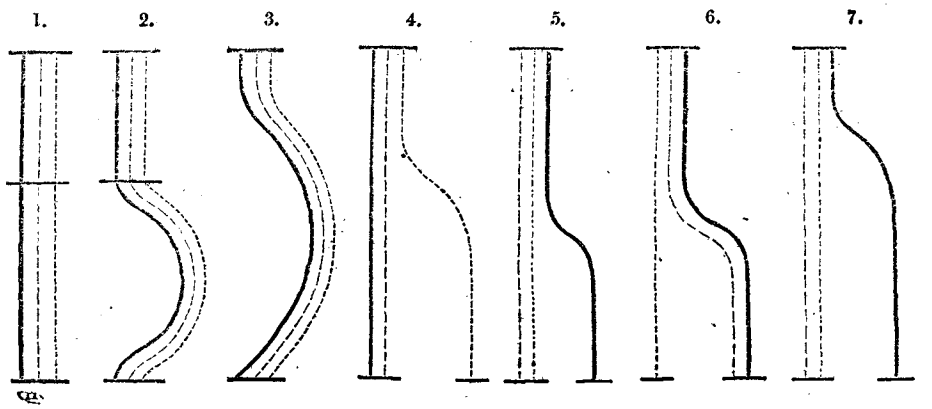
Chlorine does not liberate nitrogen of uromelanine.

Urine in acute fevers not qualitatively changed.

Generally speaking, the febrile process as exhibited in the urine is a quantitative change without final qualitative alteration. At least, so far as present information reaches, the ingredients of febrile urine do not differ qualitatively from those of healthy urine, but are present, some in increased, others like chlorides, in diminished quantities. The qualitative change which takes place in the febrile body occurs intermediately between albumen and urea; and to the rule that all anomalous products of albumen become again urea, only one disease, malignant jaundice, is at present known to form a complete exception; and even here the exception is only complete in the most extreme cases. The products of diseased action are destroyed in the blood like the pabulum of health.

It is interesting to compare with our ordinary acute fevers a number of other diseases which vary the bearing of the constituents of food and blood. Such a comparison, according to my conception of the main features, is represented in the following diagrams; where the continuous lines indicate the course of the albuminous substances, the interrupted

lines that of the fatty, and the dotted lines that of the saccharine elements of assimilated food.



Explanation of diagrams.

Diagram 1 is that of health. The three factors run through the biliary function, indicated by a horizontal line at a place about $\frac{2}{5}$ths from the top of the diagram. Diagram 2 is that of typhus fever. The three factors run through the biliary function, but deviate greatly from the normal afterwards; their products, however, return to normal qualities, *i.e.*, urea, urochrome, carbonic acid, and water, &c. The third diagram illustrates what is believed to be the course of more virulent fevers, such as yellow fever. All factors deviate immediately, the biliary function is not performed, and death occurs at the height of deviation, or the functions return to normal channels. Diagram 4 illustrates the course of diabetes. The amylon and sugar line alone deviates, and that to the end, while both albuminous and fatty matters follow the course of health. In diagram 5, that of cystine disease, the albuminous matters alone deviate, while fats and sugars retain their ordinary course. In diagram 6, that of chylous urine, sugar and starch follow the lines of health, while fats and albumen are at least in part diverted. The 7th diagram exhibits the course of malignant jaundice, in which albumen only is diverted, sugar and fat following the line of health. The disease, therefore, in these great features resembles cystine disease, but differs by the deviation of the albumen taking place before the biliary lysis has been effected upon it, while in cystine disease there is no interruption, but only a partial qualitative change of the biliary lysis, cystine being produced instead of or as well as taurine. In malignant jaundice all biliary lysis ceases at a given period, and no taurine is formed. What has here become of the sulphuretted part of albumen, which should have formed taurine (and which in the other diathesis forms cystine) is not known.

Under all circumstances the greater part of the products of diseased action is destroyed in the blood like the pabulum of health, and turned into ammonia, carbonic acid, and water, or their equivalents. Only in extreme conditions, such as diabetes, or malignant jaundice, the process of conversion indicated by one line or the other is entirely perverted, and the products of the processes indicated by that line are entirely abnormal. Thus in slight degrees or incipient stages of malignant jaundice there is as yet neither tyroine nor leucine, but the ordinary urinary products. In higher degrees tyroine and leucine appear by the side of urea, and in the ultimate fatal stages leucine and tyroine, with other abnormal products, assume the place of urea, which disappears entirely from the secretion.

Relation of urea to temperature.

In febrile diseases such as are indicated by diagrams 2 and 3, there is a certain relation of urea to temperature observed. But the explanation of this relation meets with difficulties, as several sources of error are found during its consideration. Thus it is impossible to say what was the amount of either food or tissue consumed, and consequently what kind of waste, blood or tissue waste, the urea formed represents. Next, it is impossible to tell the nature of the decomposition preceding the formation of urea, and consequently to calculate the number of units of heat evolved. And even if these were ascertained it would be practically impossible to determine the heat absorbed by the evaporation from skin and lungs, on the one, and that which has to be got rid of by radiation on the other, hand. The error arising from the excretion of a little urea by the skin is so small that it can be neglected.

In diabetes urea increases, T. is lower, carbonic acid lessened.

Generally speaking, it may be affirmed (*a*) that in all diseases with raised temperature urea is increased; (*b.*) that the process which produces urea produces the fever; and (*c.*) that the quantitative aberration is preceded by a qualitative one, as shown in the diagrams. But these three conclusions can by no means be reversed, nor are they absolute, though general, because (*d.*) urea may be increased (to double the normal standard) while temperature is lowered. This is the case in diabetes. Diminished heat and diminished excretion of carbonic acid go here hand in hand. (*e.*) Urea may be diminished in acute fever, if other products are discharged instead, the decomposition-heats of which are the cause of the increased temperature observed. (Leucine, tyroine, changed hematine.) (*f.*) These decompositions precede the urea formed by the abnormal process, and their heats are therefore superadded to the heats, which possibly may be, but are not necessarily produced by the ultimate urea formation.

Chronic diseases.

There are chronic diseases which in such respects as are here under consideration show features similar to acute. It is as if certain materials slowly accumulated in certain parts of the body, and presently split up into secondary products of diseased decomposition; this splitting up evolving heat—the same as that which was absorbed or became latent during the synthesis in which the compound was made, in the plant or animal; and the secondary products getting oxydised with further evolution of heat, till no diseased products ultimately remain. Such processes seem to be illustrated in the several stages of gout.

Nature of the specific changes.

Of the nature of the specific changes but little is known, and much remains to be ascertained. This is indeed the most difficult task of chemico-pathological inquiry. Some changes are primary, and concern matters which are yet in the intestinal canal, or already in the blood. Others are secondary or results of fever. Many brain-diseases attended by delirium, and also tetanus, are accompanied with decomposition of the sheath of the nerve-fibre, which, as shown by the reaction with perosmic acid, consists of cerebric acid; and no doubt this decomposition may be produced either by external heat radiated upon the part (as in sun-stroke) or by fever-heat operating through the blood. In acute softening of the brain this decomposition advances so far that glycero-phosphoric acid, a constant product of the decomposition of cerebric acid, is met with in the fluid which surrounds the softened part.

Glycero-phosphoric acid in softened brain matter.

Cases of diminished temperature.

It may be useful to draw attention to the causes and effects of diminished temperature, in order by the contrast to aid in the explanation of those of increased heat. The most direct and immediate cause of sinking of the animal heat is failure of the heart's action, as in a fainting fit. This, sudden and severe, may be caused by terror, or in weakened constitutions even by slight impressions on the mind. A slower but still direct cause of the same effect is external cold. It acts physically by pro-

ducing spasm. During immersion in very cold water (such as that which issues from an alpine glacier with a temperature of 8° C.) the pulse disappears, the limbs shrink, muscular spasms appear in various parts of the body, and the heart gives indications of a tendency to arrest its action. When elements for the production of heat are abstracted from the body (as in starvation, bleeding, and diarrhœa) the same result occurs. And it also forms part of the state of collapse which many poisons (common and morbid) produce. Partial paralysis acts by loss of motion only, but complete paralysis, such as paraplegia, *e.g.*, by severing of the spinal marrow, causes at first a great rise in the temperature. Sections of one side of the spinal marrow produce paralysis of motion with diminished heat on the one, and increased heat and hyperæsthesia on the other side.

During the impairment of chemical action in diminished temperature, matters collect which afterwards when they become oxydised (with or without accidental assistance from exterior circumstances) cause an increase of temperature, or so-called reaction. But abnormal matters may also collect by being produced quicker than they can be oxydised, and when they are got rid of by the economy it is also by the process of reaction. Reaction (the manifestation of the chemical destruction of collected abnormal matters) begins with a period termed crisis; and crisis I understand to be the point at which more morbid material is beginning to be oxydised than is produced in equal times.

Chemical definition of "reaction."

Chemical definition of "crisis."

I have not been able to convince myself of the existence of critical days, as defined by Traube, namely, the uneven days from the beginning of the disease. Though there might be clinical appearances, the chemical phenomena did not keep parallel to them. The circumstance that in intermittent fever reaction and crisis are indefinitely repeated in definite intervals, points to a limitation of the length of time during which abnormal matters may collect. In remittent fever the intervals are in closer approximation and observe no regular periodicity. In typhus and yellow fever, crisis and reaction are compressed within a very short span of time, and may be possibly imperceptible unless measurements and analyses are made at such short intervals as two hours.

Critical days doubtful.

Crisis in intermittent fever.

Crisis in typhus and yellow fever.

In chronic diseases, on the other hand, crisis and reaction occur at very long intervals. Thus in chronic intermittens, I have observed them every 28 days in the male subject. Gout, again, may show them at intervals of weeks, months, or years. However intervals may vary, the process shows the same course and derivation.

Crisis in chronic diseases.

Carbon leaves the body in breath and urine. In the breath it occurs as carbonic acid and as carburetted hydrogen. The latter in health appears in small quantity, but may perhaps be increased in diseases. The symptomatology of the tongue may be enriched by observations on this point. For abnormal gases during expiration may exercise an influence upon the tongue as well as morbid kinds of saliva and buccal secretions. The origin of the carburetted hydrogen gas is mostly in the intestinal canal. As marsh-gas, CH_4, it is a regular constituent of flatus, and of those great and painful collections of gas which produce the tympanites of abdominal typhus. Possibly carbonic acid gas may be secreted from the blood into the intestine when the lungs fail in action. Thus in hydrothorax I have repeatedly observed tympanites and continued eructation of gas. These considerations derive great support from the conception of respiration as being primarily an act of secretion, before it becomes one of absorption as well. But the fact has to be borne in mind, that most of the gas which occurs in the intestinal canal is the product of the decomposition of its contents.

Collateral features of the chemistry of fever.

Abnormal gases.

Marsh-gas in tympanites of typhus.

A measure of disintegration of blood-corpuscles wanted.

The significance of the various nitrogenous bodies in the form of which nitrogen leaves the body during fever, and their relation to each other, can only be found by continued quantitative researches. What we know of urea almost suffices for a theory in which all factors are in harmony. But we must have a measure of the disintegration of the blood, and that we can only find in uromelanine, or better still in a method of determining urochrome with the same despatch as urea. With such a measure we could ascertain the quantitative effects of fever far better than with the thermometer or urea analysis alone. The thermometer gives us a measure of the aggregate chemical changes; the urea a measure of the disintegration of albumen; but urochrome would show us the amount of disintegration of the corpuscular respiring and oxydising part of the blood. Much of the efforts of pathologists must therefore be directed upon obtaining this aid; and consequently my researches of the last two years have lain very particularly in this direction.

B.—*Waxy Degeneration, particularly of the Liver.*

Bacony liver, &c., discovered by Rokitansky.

Waxy degeneration affecting most organs of the body was first described by Rokitansky. He termed it bacony degeneration (Speck-leber) on account of the peculiar consistence which organs, *e.g.*, the liver, assume under its influence. He observed peculiar corpuscles from the size of granules to that of larger animal cells, some of the larger ones of which showed concentric rings. On account of their peculiar consistence, and their tendency to break up under slight pressure like drops of cold jelly, he termed them *colloid* corpuscles. He thus applied to a microscopic formation, the result of the morbid metamorphosis of a natural tissue, an adjective which Laennec had applied to a peculiar kind of tumor, a new growth. Some of the peculiar corpuscles exhibiting a concentrically stratified appearance, Rokitansky following Purkinje, termed (first variety) amylaceous bodies, others (the second variety) he termed *stratified colloid* corpuscles. (Pathol. Anatom. 1, 116.) Virchow examining these corpuscles by means of iodine, observed that they assumed colorations varying from pale blue to blue grey, violet, and brownish, but never purely violet or blue; on subsequent addition of sulphuric acid they assumed a blue, violet, or violet brown colour. This induced him to term the bodies *amyloid* corpuscles, and to attribute to them the properties of cellulose. (Virchow's Archiv. 6, 135; 6, 268; 6, 416; 8, 140; 8, 364.) Busk assented to this because he saw that the corpuscles became blue by the influence of chloride of zinc-iodine (Quarterly Journal of Microscopic Science, 1854, January). It was, however, often observed that organs which had the general characters of this degeneration with iodine and sulphuric acid gave only a mahogany coloration, and no blue whatever. (See Drs. Bristowe and Ord, in Path. Trans. Vol. X.) And an analysis of an extract by potash from a bacony liver, made by Kekulé, had yielded data which showed the extract to possess the composition of an albuminous body. It became, therefore, necessary to establish a distinction between the bacony, or as it is now termed waxy, and the amyloid degeneration, and to examine the chemical differences between the two processes.

Difference between colloid degeneration and colloid tumors.

Amyloid corpuscles.

Distinction between waxy and amyloid degeneration.

An exquisite specimen of a waxy liver from a patient who had been under the care of Mr. Simon was therefore subjected to the following examination. A part of the liver was ground to a pulp, extracted with cold water and filtered. The solution with a little acetic acid, or by itself on boiling, as also with nitric acid, and subnitrite of mercury

(Millon's reagent), gave the reaction of albumen. Evaporated, the residue extracted with alcohol, after evaporation of the alcohol a solution was obtained which gave no reaction with Trommer's test. Consequently sugar was not present in the extract.

Another part of the liver was repeatedly extracted with boiling water, and the extracts were united and evaporated to a syrupy consistence. Pettenkofer's test gave no reaction, so that bile-acids were absent. No sugar could be detected either in the residue or its evaporated alcoholic extract.

Cold water extract contains albumen, no sugar.

The pulp, which had been extracted with hot water, was boiled with alcohol, and the decoction filtered hot. The filtrate was evaporated to dryness and redissolved in a small quantity of boiling absolute alcohol. On cooling of this solution a considerable quantity of cholesterine was deposited. The crystals were mixed with drops of fat. The filtrate from this deposit was again tested for biliary acids, but none were found. With nitric acid a feeble reaction of green, blue, and violet was obtained. As the alcohol reacted rather violently with the acid, the solution was diluted with twice its bulk of water, whereby a milky precipitate ensued. This was completely soluble in much acetic acid (fatty acids). When to the turbid solution chloride of iron was added a dark yellow precipitate ensued, which may have been benzoate or succinate of iron.

Hot water extract contains no bile-acids, no sugar.

Alcohol extract.

Contains cholesterine, no bile-acids, little cholophæine.

Fatty acids.

A part of the liver was comminuted and heated with hydrochloric acid. The dark purple solution was filtered, heated on the water bath, and treated with small quantities of chlorate of potash, until the fluid ceased to froth and was clear yellow. On the top there was some fat, at the bottom of the fluid there was a small quantity of a yellow flaky precipitate. This was easily soluble in alcohol. It follows from this that gelatine is absent, and that the main bulk of the matter behaves like syntonine.

Benzoic or succinic acid.

No gelatine, but syntonine.

No part of the liver, fresh or extracted with alcohol, gave with iodine, or iodine and sulphuric acid, any reaction indicating the presence of amyloid or cellulose matters. The particles only assumed a mahogany brown colour.

No amyloid reaction.

Results.—The waxy liver contained of abnormal substances syntonine, cholesterine, and benzoic or succinic acid. Biliary acids and sugar were (abnormally) absent; a trace of cholophæine was present. Only very little fat was met with. Consequently the degeneration consists mainly in the displacement of gelatiniform tissue, and the disappearance of sugar and biliary acids, with the abnormal deposition of syntonine (or a matter behaving like syntonine) and cholesterine.

Results.

C.—*Determination of the Quantity of Sugar circulating in the Blood in a case of Diabetes.*

It has been affirmed that the proximate cause of the symptoms of diabetes is melitæmia. And undoubtedly sugar has been found abundantly in blood examined in the usual way after withdrawal from veins. But it was not quite certain that all this sugar, or any of it, existed in the blood while circulating, and that there had not been a post-mortem or rather a post-venesectionem change of some glycogenous material into sugar. Moved by these considerations Mr. Simon suggested the following experiment, which was accordingly carried out at St. Thomas's Hospital. 69 grammes of blood were withdrawn by venesection from the arm of a female diabetic patient. Of these 29 grammes were received directly into 75 grammes of absolute alcohol yielding 104 parts of mix-

Question.

Experiment.

Result.

ture. This after two filtrations was by nitric acid and boiling found free from albumen. It was now examined with a saccharometer, to be more fully described in the following. In this apparatus a diabetic sugar solution of 4·75 °/₀ compensated (a) 0·72; (b) 0·71; (c) 0·71 = mean 0·71 inches of scale adjusted to left turning oil of turpentine. The blood extract compensated 0·01 inch, equal to $\frac{4.76}{71}$ = 0·067 °/₀ of sugar in mixture. Multiplying this by $\frac{104}{29}$ = 3·58 we get 0·2398 °/₀ of sugar in blood. Taking the whole of the patient's blood at 4,500 cubic centimetres, it would after that rate contain 10·8 grammes of sugar. The second portion of blood, measuring 40 cubic centimetres, which had been drawn with the above, but not into alcohol, was after 24 hrs. standing treated in exactly the same manner as blood 1. Blood 40 gms., alcohol 103 gms., mixture 143 gms. In the saccharometer the filtered mixture compensated exactly 0·01 inch of left-turning turpentine. Consequently this second blood contained neither more nor less sugar than the first. The alcoholic extracts, after evaporation of the alcohol and resolution of the residue in water, gave the test for sugar with alkaline copper solution.

Jellett's polarimeter.

Jellett's Polariscope.—The foregoing observations were made with a polarimeter which was invented a few years ago by Mr. J. H. Jellett, Professor of Natural Philosophy in the University of Dublin. As this instrument is by far the most accurate polarimeter extant, but is nevertheless little known and less used, I think it almost a duty to give a short description of it in this place, accompanied with such illustrations as will make its construction readily understood. The description will closely follow the inventor's account, as given in vol. vii. of the Proceedings of the Royal Irish Academy. The instrument represented in the woodcut, and which was employed in the foregoing analyses, is by Mr. Spencer, philosophical instrument maker, of Dublin.

Drawbacks of ordinary Nicol's prism.

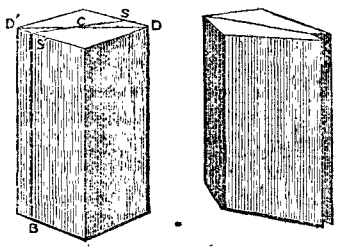
In determining the plane of polarization of a ray by means of the ordinary Nicol's prism, the observer is required to arrest the rotation of the prism at the point at which the intensity of the transmitted light is at a minimum. But it is difficult to do this with very great accuracy, inasmuch as the observer is obliged to compare a shade of colour not with any other shade which is before his eyes at the same instant, but with his recollection of a shade observed at the previous instant. To insure any tolerable degree of accuracy the observation must be made very rapidly, so that the eye may receive the new impression while the former one is still quite fresh in the memory. The difficulty of doing this with accuracy in any case is obvious, but it is most felt in experimenting on light reflected or transmitted by fluids. For here it is impossible to touch the instrument without producing a tremulous motion in the fluid, and therefore in the image reflected or transmitted; and this motion while it lasts renders accurate observation very difficult. But if the rotation of the analysing prism be stopped for a sufficient length of time to allow this motion to cease, the recollection of the previously existing tint will no longer be so fresh as to allow the comparison to be made with any very great exactness. The difficulty will be increased, as is easily seen, when there is any amount of elliptic polarization in the light which is to be examined.

Remedy by simultaneous tints.

The remedy for this difficulty Mr. Jellett sought in the construction of an analyser in which the tints compared should be *simultaneous*, not consecutive. The double quartz plate of Arago was an attempt to realize this conception. It has, however, no similarity in principle to, and does not approach in accuracy, the following instrument devised for this purpose by Professor Jellett.

A rhombic prism of Iceland spar, whose longitudinal edges should have a length of about two inches, or a little more, is cut by two planes perpendicular to those edges, so as to form a right prism, as in the engraving, Fig. 1.

Fig. 1. Fig. 2.



Prism cut and divided.

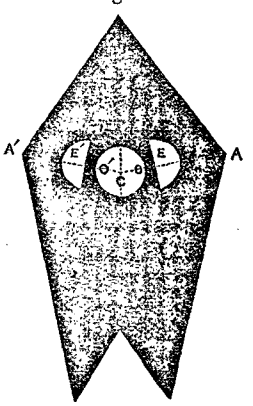
This prism is next divided by a plane S S′ B, parallel to the edges and making a small angle with the longer diagonal of the terminal face D′ D; one of the two parts into which the prism is thus divided is then reversed, so as to place the base uppermost; the two parts are cemented together, as in Fig. 2, with the surfaces of section in contact, and the ends of the prism thus formed are then ground and polished.

One half of prism turned 180° round centre of plane of section.

Now it is evident from the construction of the prism, that if two rays of light parallel to the axis be made to traverse the two parts of the prism respectively, the lines of separation of the ordinary and extraordinary images in these two parts will be C A, C A′, Fig. 3; and as the angle between the plane of section and the longer diagonal is small, the angle A C A′ is nearly 180°. Hence the extraordinary refractions in the two parts are in nearly opposite directions; and if the end at which the light is admitted be so chosen that these refractions shall be *from* the plane of section, the separation of the images will be nearly doubled.

Peculiar refraction in new prism.

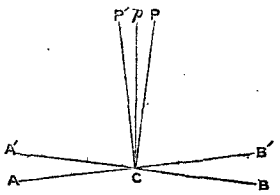
Fig. 3.



Now suppose a circular beam of plane-polarized light to traverse the prism in a direction parallel to the sides, and so as to be equally divided by the plane of section, the emergent beam will consist of three separate parts, viz., (1) a circular beam, O C O′, Fig. 3, formed by the union of the two ordinary beams; (2) two semicircular extraordinary beams, E E′. If, then, the size of the incident beam be suitably determined, these latter may be completely separated from the ordinary beam, so as to admit of their being stopped by a diaphragm which allows the ordinary beam to pass; the instrument will then transmit a single beam of plane polarized light.

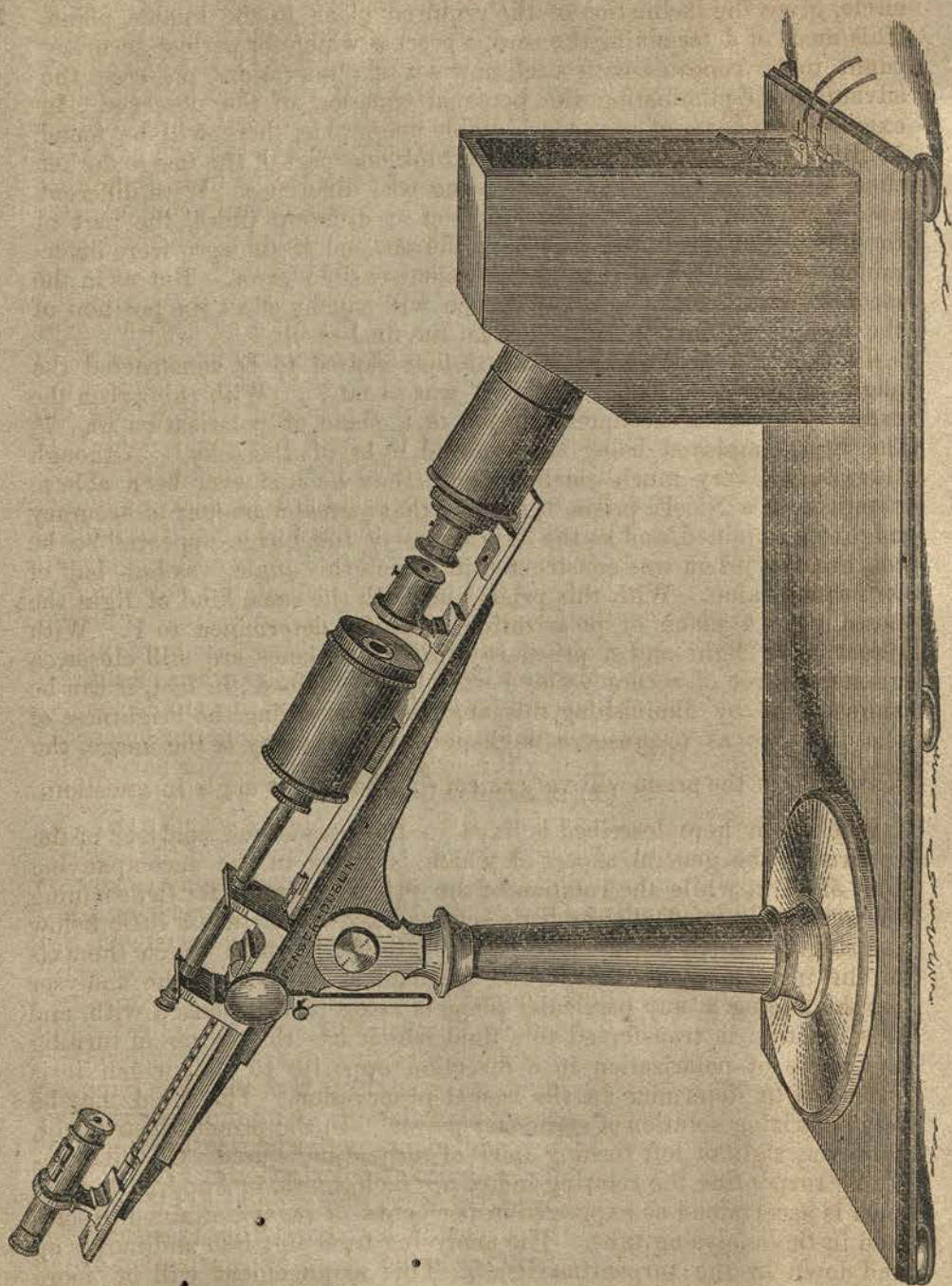
Now it is easy to see that the planes of polarization of the two parts into which the beam is divided by the plane of section are inclined to each other at an angle somewhat less than double the angle D C S, Fig. 1. Suppose, then, that the plane of the paper being perpendicular to the beam, the traces of these planes of polarization are represented by A B, A′ B′, Fig. 4, and let C P and C P′ be perpendicular to these lines respectively. Let C p be the plane of polarization of the ray to be examined.

Fig. 4.



Then so long as there is any difference between the angles P C p, P′C p, the intensities of the two parts of the beam will be different, and conversely, if these intensities be equal, it is evident that the required plane of polarization will bisect the angle P C P′. The prism must therefore be turned on its axis until the equality of tints be established, and when this is done, the position C p of the plane of polarization is known. It is not, how-

Fig. 5.



ever, necessary to determine the position of the planes P C, P′ C. The observer commences by transmitting a beam whose plane of polarization is known, and turning the analysing prism until the tints become equal. The beam whose plane is required is then introduced, and when the equality of tints has been re-established, the angle through which the prism has revolved, read off on a graduated circle, gives the inclination of the required plane to the known plane. This mode of determining the zero, a process which for perfect accuracy ought to be repeated with each new set of observations, possesses the advantage of eliminating the personal equation of the observer. In examining a beam of any considerable magnitude, there will be found in different persons a tendency to think one part of the image darker than another, even when there is no real difference. With different observers, and even in the same person at different times, the part of the image thus preferred may be different, and if the zero were determined once for all this might occasion sensible error. But as in the method here given such a preference will equally affect the position of the zero, it can have no influence on the final result.

In the first prism which Prof. Jellett caused to be constructed the angle between the planes C P, C P′ was about 7°. With this prism the range of error in the determination of a plane of polarization was 7′, the light employed being the diffused light of the sky. Although this was a very much smaller range than he had ever been able to obtain with a Nicol's prism, it seemed that a greater amount of accuracy might be obtained, and as the brightness of the image appeared to be too great, a prism was constructed in which this angle was but half of its former value. With this prism and with the same kind of light the position of a plane of polarization could be determined to 1′. With direct solar light and a prism in which the planes are still closer, a greater degree of accuracy may certainly be obtained; in fact, it can be shown that by diminishing this angle and increasing the brightness of the light, so as to preserve unchanged the intensity of the image, the sensibility of the prism will vary as $\cot \frac{\theta}{2}$, θ being the angle in question.

The prism here described is fixed in the eyepiece or analyser of the apparatus, the general aspect of which is given in the accompanying Fig. 5. But while the rotation of the prism necessary for determining the zero point is effected by little screws fixed to the tube a little below the ring by which the eyepiece is fixed to the beam on which the axis of the instrument is carried, the mechanical rotation of the analyser for the finding of any particular plane is altogether dispensed with, and this function is transferred to a fluid which has the power of turning the plane of polarization in a direction opposite to that which it is intended to determine in the casual observation. This fluid may be any polarizing solution of stationary power. In the present instrument, however, right or left turning spirit of turpentine is used. Of this polarizing turpentine the rotating index per inch, tenth, or hundredth of an inch is ascertained as expressed in per cents. of sugar contained in solution in the analysing tube. The analysing tube dips into and moves up and down in the turpentine itself. This arrangement will be more intelligible by the aid of the subjoined Fig. 6.

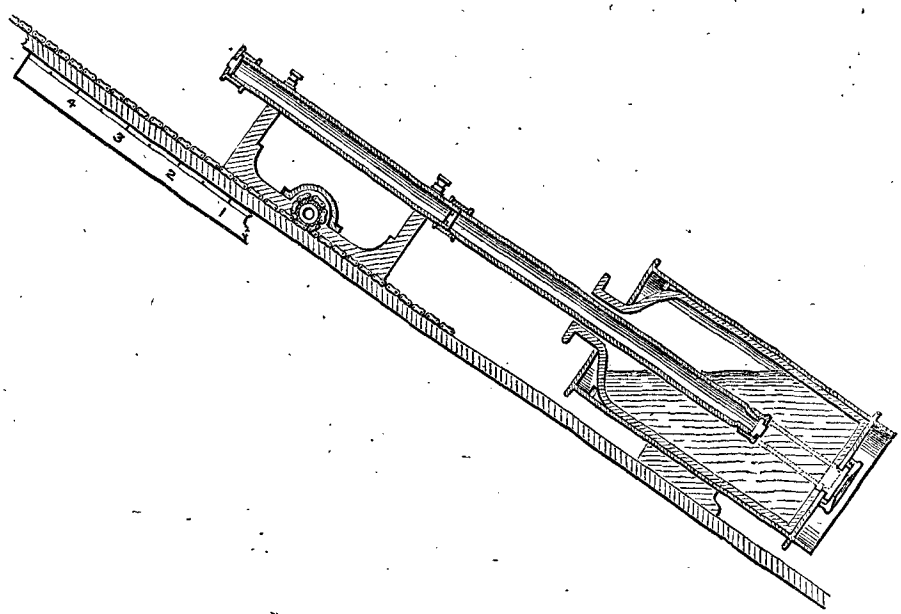
Fixing of the zero point.

The order of events in an actual analysis now is as follows: (1.) *Finding of the zero point.* A beam of parallel light produced in the closed box at the end of the apparatus, by means of the oxyhydrogen-calcium light and a compound condenser, is thrown in the direction of the optical axis of the apparatus. It passes first through the polarizing prism. The polarized beam then enters the bottom of the turpentine bottle. The long tube containing water is pushed down to the bottom

Finding the index of the turpentine.

of the turpentine bottle, until its glass plate rests upon the plain surface of the inside of the turpentine bottle. The arrow of the indicator is placed upon the zero point of the scale attached to the side (of which a portion is represented in Fig. 6), and the analysing eyepiece is now turned until the tints of the half-circles of its picture are equal. (2.) *Finding of the index of the turpentine as expressed in per cents of sugar.* The tube containing water, and intended to contain the fluid to be analysed, is now filled with a solution of dextrose sugar containing 10 per cent. of sugar, which turns the plane of polarization to the right. If the tube be replaced as before, the tints of the picture in the analyser will now be unequal. The tube carrying the sugar solution is now raised upwards by means of the milled-headed wheel, until the tints of the two halves of the picture in the analyser are again equal. By that means a column of oil of turpentine (turning to the left) will have been inter-

Fig. 6.



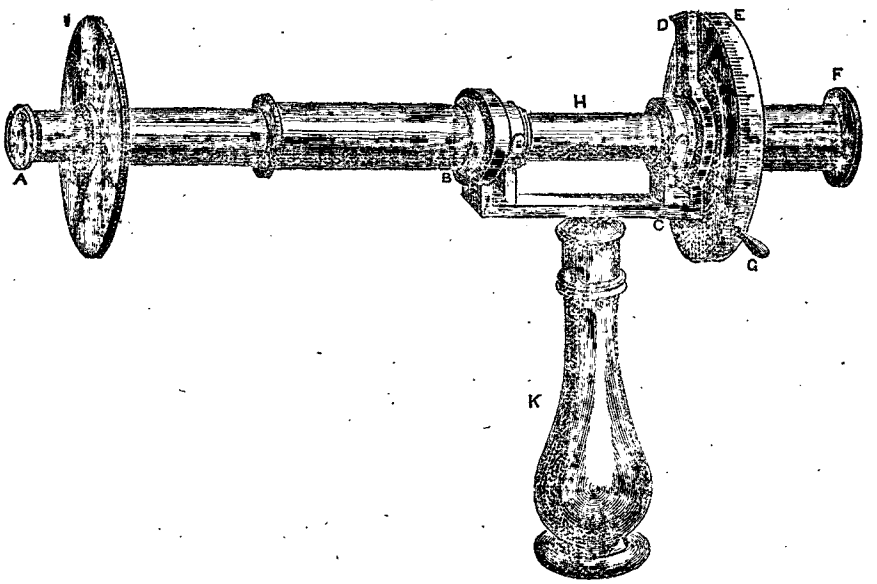
posed between the sugar solution and the polarizer (as shown in Fig. 6), which turns the plane of polarization as much to the left, as the tube full of ten per-centic sugar solution turns the plane of polarization to the right. Both polarizations will have completely neutralised each other. Supposing the arrow stand upon 1 of the scale, then a column of one inch of left-turning turpentine has been required to neutralise the polarization of a solution of 10 per cent. of sugar in the tube. If now a solution containing either more or less sugar be placed into the tube, a longer or shorter column of turpentine will be required to neutralise its effects. And as the effect of a column of one inch (in the above example) is known to indicate 10 per cent., the effect of any length, or its sugar-indication, can be found by the equation $1 : 10 = t : x$, in which t is the length of the turpentine column measured on the scale, and x the per-centage of sugar contained in the problematical fluid in the tube. I have not entered into minor details of the construction of this apparatus, such as the chain in connexion with the milled wheel by which the closed tube is moved up and down in the turpentine bottle, or the long lever attached to the milled wheel for

delicate adjustment. These must be studied upon the apparatus itself, and like the entire apparatus itself will be found to leave nothing to be desired in respect of mechanism. No other polarimeter approaches this instrument in accuracy for such saccharometrical purposes, as with care it indicates 0·01 °/₀ of sugar. But its disadvantages are that it requires powerful artificial light, that it is cumbrous and complicated and must be skilfully managed, and that its price is necessarily very high. It cannot yet be made to indicate the polarization of any particular ray of light, say the yellow or the green, and it will probably be better not to attempt to complicate it with any arrangement for that purpose.

Wild's Polarimeter.—This instrument, represented in Fig. 7, is very handy for general purposes in which only approximative results are required. It is held by the hand at K, and A is directed towards the

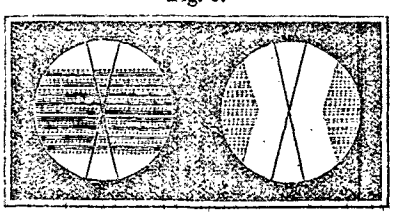
Wild's polarimeter.

Fig. 7.



light of a candle, oil-lamp, or gaslight, while the eye is applied at F. At A the tube contains a Nicol's prism. At B a Savart's polariscope is fixed consisting of thick pieces of quartz with intermediate lenses and a wire cross of the shape represented in Fig. 8. The eyepiece F carries a second Nicol's prism, which turns with the disk E, carrying the division of the circle on its circumference. For the greater convenience of manipulation a lever G is fixed in the disk. The zero point and nonius are immoveable at D, and B C is the arrangement by which the handle is fixed to the instrument. I is a black disk, intended to further screen the eye from the direct light, and H is the tube in which the fluid to be examined is placed. When the eye receives the transmitted light of the apparatus, while the divided circle is in any position except those where 0°, 90°, 180°, 270° are exactly incident with the zero mark of D, then a

Fig. 8.



picture sketched in the left-hand circle of Fig. 8 is seen, consisting of striæ of interference running horizontally through the entire field of vision. But when 0°, 90°, 180°, or 270° are placed exactly upon the zero point at D, the transverse striæ are not visible in the middle of the field, where now the wire-cross alone is visible, as represented in the right-hand circle of Fig. 8. If now the tube X is filled with any fluid possessing the property of circular polarization, and is placed into the position indicated in the engraving, and if at the same time the zero point at D is made coincident with 0° of the rotating disk, the striæ of interference will be visible, and will only disappear after the disk E has been turned a little to the right or to the left. In case the fluid contained in the tube H causes a rotation above 5°, the striæ of interference only become weaker, but do not disappear entirely from the middle of the field of vision in any position. If the rotation was less than 5°, and the point has been attained at which, as in Fig. 8, II., the interference striæ in the middle of the field of vision have disappeared, the observer may read the amount of rotation towards the left or right side which the fluid has effected by reference to the scale.

In case the rotation of the fluid amounts to more than 5°, it is advantageous to employ monochromatic light for determining the amount of polarization. This may be done simply by fixing a plate of red glass before the aperture A, or using as the source of light a spirit flame the wick of which has been drenched with common salt. With such light the striæ by interference disappear at a certain position of the analyser, may the rotation be ever so great.

I am engaged in elaborating a combination of the method of Broch for determining the specific rotation of polarizing fluids with my spectro meter. Dr. A. Dupré has also informed me that he has elaborated a new polariscope, but the mechanical details of these attempts are not yet completed, and their description must therefore be reserved for a future opportunity. Seeing how many of the fluids or products of the animal body possess polarizing action, albumen, gelatine, the various sugars and dextrines, biliary acids, and others, we are not likely to form an exaggerated estimate of the value of an accurate yet ready and expeditious method of polariscopy and polarimetry for physiological and pathological research.

D, E, F.—*Further Researches on Urochrome.*

Synopsis of the Products of Chemolysis of Urochrome.

A. Fixed Products of Decomposition by Sulphuric Acid.

Insoluble in ether, all soluble in ammonia.	Uromelanine	Insoluble in alcohol.
	Uropittine	Soluble, sparingly, in alcohol.
	Urorubine	Soluble, easily, in alcohol.
	Metauropittine	Soluble in alcohol.
Soluble in ether and alcohol.	Omicholine	Insoluble in ammonia.
	Omicholic acid	Soluble in ammonia.

B. Volatile Products of Decomposition by Sulphuric Acid.

Soluble in ether		Essential oil.
As sodium salts insoluble in ether.	Acetic acid.	
	Uncertain volatile acids.	

D.—*Omicholine; and* E.—*Omicholic Acid.*

Synopsis of the Preparations of Omicholine and Omicholic Acid obtained in this research.

A. I. A. II.	used up in first analyses and tests.	
A. III.	Putrid urine.	
B. I. B. II. B. III.	United as B.	*a.* Portion insoluble in NH_3, or omicholine. Three elementary analyses. *b.* Portion soluble in NH_3, or omicholic acid. Two elementary analyses.
C. I. D. I.	Before boiling therefore united as C.	*a.* Portion insoluble, or omicholine. Four elementary analyses. *b.* Portion insoluble, or omicholic acid. Two elementary analyses.
C. II. D. II. D. III. D. IV.	United as D. (with C.) after boiling.	*a.* Portion insoluble in NH_3, or omicholine. Three elementary analyses. *b.* Portion soluble in NH_3, or omicholic acid. Four elementary analyses.

Mode of obtaining.—The mixture of substances which alcohol extracts from the chemolytic products of urochrome (which are insoluble in the acid mother liquor and in water) is evaporated to a small bulk, and then poured into water. The precipitate is collected on a filter and washed until all traces of impurities have disappeared from the filtrates. The matter is now allowed to dry spontaneously, or in vacuo over sulphuric acid (not by heat, as the matter fuses and penetrates into or through the paper), and then in a flask extracted with ether. This operation is very difficult, as the matter cannot be powdered, and in the ether immediately settles in the form of smeary hard lumps. However, after weeks of continued extraction all resinous matter has passed into the ether, and a pulverulent matter, uropittine (perhaps urorubine), and some uromelanine, remain undissolved. The ethereal solution is of a bright port-wine red colour, and peculiar, independently of the ether, penetrating odour. When the ether is allowed to evaporate spontaneously, or distilled off, a red syrup remains, which may become hard, but never shows any signs of crystallisation. It was this body which I had described as omicholic acid in the Hastings Prize Essay. The following will show that it is a mixture of two closely related bodies, which can, however, be separated to some extent, though imperfectly.

Mode of obtaining omicholine, &c.

Mode of separating Omicholine from Omicholic Acid.—The resin is treated with concentrated liquor ammoniæ and warmed. A portion dissolves, while another portion settles as a thick brown oily liquid. The alkaline solution is decanted and allowed to stand, when it will deposit more of the oily matter. (This portion is rejected, as being probably a mixture of omicholine and omicholic acid, which it is impossible entirely to separate.) When the alkaline solution in a covered vessel does not deposit any more oily matter, it is considered free from omicholine, and to contain only omicholic acid dissolved with ammonia, and some uropittine. The deposit is omicholine.

Separation of omicholine from omicholic acid.

Purification of Omicholic Acid.—To the watery ammonia solution some $BaCl_2$ is given, which precipitates most of the uropittine and any trace of uromelanine which may be present. (The Ba salt in one case gave 20 °/₀ Ba.) The filtrate is acidified with hydrochloric acid, which precipitates all omicholic acid as resin. It is washed with cold water.

If no uropittine be discovered by testing, sulphuric acid is added to the ammonia solution. In this case a precipitate ensues, but much omicholic acid remains in solution. On evaporation of the acid liquid it is deposited in drops. All omicholic acid is easily taken up by ether from the acid watery liquid or mixture.

Purification of Omicholine.—The deposited omicholine is mostly free from uropittine and uromelanine, which easily dissolve in the watery ammonia; but it must be well washed with water, and a trace of acid, before it is pure.

Ultimate purification by ether.

Ultimate Purification of Omicholine and Omicholic Acid.—Each of these bodies is dissolved in absolute alcohol, and to this solution six volumes of absolute ether are added. Any precipitate is impurity, either uropittine or other matter. When the mixture remains clear the matter dissolved in it, provided it has been treated as above stated, must be considered as pure as in the present state of our knowledge it can be obtained.

Chemical properties of omicholine.

Chemical Properties of Omicholine.—It is semi-fluid to resinous, becoming harder by keeping. It has a red colour and strong peculiar odour. It is little soluble, or insoluble in concentrated caustic ammonia, and does not combine with barium salts. It is soluble in caustic potash, and again precipitated by sulphuric acid. It is a little soluble in cold water on standing, a little more soluble in boiling water, with a yellow colour; the solution becomes turbid on cooling. The cold watery solution becomes turbid on addition of a little sulphuric acid; on heating it clears up again. The watery solution, hot or cold, gives a precipitate with (1) sulphuric acid and iodine dissolved in iodide; (2) with mercury oxyde nitrate, yellow white; (3) with the same and subnitrite or nitrite of suboxyde a red reaction like tyroine. All watery solutions are strongly fluorescent. Silver nitrate gives no immediate precipitate in the hot saturated watery solution, but on standing a precipitate is formed. Its spectral phenomena are most remarkable, and have already been alluded to on p. 271 of the Report for 1868. The ether solution is of a ruby red colour, but fluoresces green in the cone of the sunlight. In the spectroscope it shows an absorption band in green.

$$141^\circ\ 42' - 141^\circ\ 12' = 0^\circ\ 30'\ \text{Int. 5. R. } \alpha.$$

Near to it in green there is a shading.

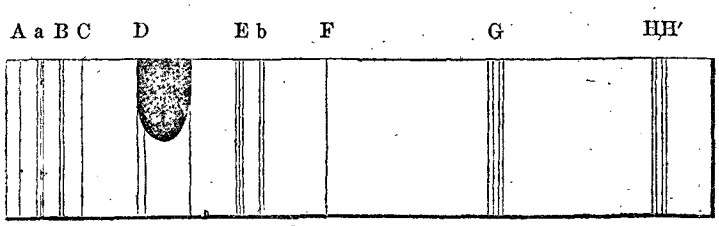


Diagram of Spectrum of Omicholine.

The red and yellow are very brilliant; the rest of the spectrum after green has a violet hue, without any blue.

Physical and Chemical Properties of Omicholic Acid.—This acid is of a red colour, resinous, fusing when heated, and giving out the aromatic strong odour reminding of castoreum. It is little soluble in water, more in ether, best in absolute alcohol. It dissolves in concentrated watery

ammonia, and more easily in caustic potash. The ether solution, which is ruby red, shows an absorption band in green.

141° 36′—141° 18′ = 0° 18′. Int. 5. R. α.

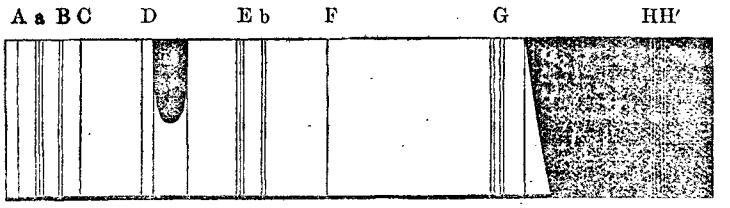


Diagram of Spectrum of Omicholic Acid.

The blue part of the spectrum is coloured violet. Green shaded at 141° 12′. Omicholic acid in chloroform has the same spectrum; but as the solution can be obtained more concentrated than the ether solution, the violet, blue, and nearly the whole of the green part of the spectrum, are cut off entirely immediately to the right of the absorption band. The ammoniacal solution of omicholic acid has no bands in the spectrum. Omicholic acid is red and fluoresces green in the sunlight-cone, or that of the electrical lamp, but its phenomena differ slightly from those of omicholine.

Elementary Composition of Omicholine.

The specimens A. I. and A. II., described originally in the Hastings Prize Essay, when lately again examined had been dried and kept in vacuo for three years. They were reddish-black, tough, hard, easily fusing in heat, and of the most powerful peculiar odour. Six elementary analyses gave results such as might be expected from a mixture of omicholine and omicholic acid, of which the substance was subsequently found to consist. Specimen A.

Omicholine and Omicholic Acid. Specimen B.

This specimen was suspected to contain traces of uropittine and uroru-bine, and upon it were performed most of the experiments which led to the information relating to the separation of omicholine and omicholic acid given in the foregoing. The drops of omicholine, which before treatment with ammonia had been acid, after removal of omicholic acid, and much washing with water, remained alkaline. Specimen B.

From the omicholic acid in ammonia $\cancel{Ba}$ Cl_2 precipitated flakes which were dried at 100; 0·3364 grm. left after burning and heating with ammonium carbonate 0·1069 grm. barium carbonate, equal to 20·28 °/₀ of $\cancel{Ba}$ (uropittate). From the filtrates omicholic acid was recovered by the addition of hydrochloric acid.

Elementary Composition of Omicholine. B, a.

1. Dried at 85° C. 0·2621 burned with lead chromate, lastly with oxygen, gave 0·6268 $\cancel{C}\cancel{O}_2$ and 0·2318 $H_2\cancel{O}$, equal to 65·22 °/₀ $\cancel{C}$ and 9·82 °/₀ H. Elementary composition of omicholine.

2. 0·1306 burned as before gave 0·3071 $\cancel{C}\cancel{O}_2$ and 0·1207 $H_2\cancel{O}$, equal to 64·13 °/₀ $\cancel{C}$ and 10·26 °/₀ H.

3. 0·1754 burned with soda-lime, &c., left 0·0396 $\cancel{Pt}$, equal to 3·20 °/₀ N.

Found mean by analyses.

		Quotient by At. W.	Quotient by N = 1.
C	64·67	5·3891	23·5
H	10·04	10·0400	43·9
N	3·20	0·2285	1·
O	22·09	1·3806	6·04

Leading to formula $C_{24}\ H_{44}\ NO_6$.

Elementary Composition of Omicholic Acid. B, b.

Dried for 48 hours at 85° C. Contained a trace of iron.

1. 0·2042 burned in lead chromate, ultimately in oxygen, gave 0·4766 CO_2 and 0·1496 H_2O, equal to 63·65 °/₀ C and 8·14 °/₀ H.

2. 0·2892 burned in soda-lime gave 0·0952 Pt, equal to 4·67 °/₀ N,

	In 100.	Quot. by At. W.	Quot. by N = 1.
C	63·65	5·304	15·92
H	8·14	8·140	24·44
N	4·67	0·333	1·
O	23·54	1·471	4.41

Formula $C_{16}\ H_{24}\ NO_4$.

Synopsis of Preparations from Resins C.

Omicholine and Omicholic Acid.

Omicholine, C, a.
Omicholic acid, C, a.
Omicholine, C, b. } Contained Ba salt 17·17 °/₀.
Omicholic acid, C, b. }
United form Omicholine, C, a. } With which O. and Oc. acid from
and Omicholic acid, C, b. } DI are united.

Uropittine.

Uropittine, C, α, 1 (∿ from cold alc.),* Ba salt : 20·21 °/₀ Ba; Ag. salt : 21·39 °/₀ Ag. Peculiar Bearing with NH_3.
Uropittine, C, α, 2 (∿ by ether). 4 elementary analyses.
Uropittine, C, α, 3 (∿ by ether). Ag salt, boiled : 38·71 °/₀ Ag. Other salt, not boiled, 35·49 °/₀; Ag; Ba salt 7·1 °/₀ Ba.
Uropittine, C, β, 1 (depos. from alc.) Ca salt : 1·78 °/₀ Ca; 12·16 °/₀ N.
Uropittine, C, β, 2 (do. on concentration) Ba salt : 21·77 °/₀ Ba Ag salt, 27·14 °/₀ Ag.
Uropittine, C, β, 3 (∿ by 5 vols. of ether). Ag. salt : 27 °/₀ Ag.

Uromelanine.

Uromelanine, C.

Treatment of the mixed Resins C.

(*a.*) *Extraction by cold Ether. Isolation of Omicholine and Omicholic Acid.*

The mixture was exhausted with cold ether, which assumed a port-wine red colour, becoming lighter at every operation. The ether was

* The symbol (∿) indicates "precipitated."

evaporated until a residue of oily consistence remained, which was found to be a mixture of two bodies, omicholine and omicholic acid. They were separated as follows—

Separation of Omicholine, C, a, from Omicholic Acid C, b.

The oily resinous residue was treated warm with a large bulk of concentrated watery solution of ammonia. One part dissolved and remained dissolved on cooling, *omicholic acid*,—another part remained insoluble, *omicholine*. The latter represented a liquid resin of strong smell, and appeared to possess most of the qualities of the substance termed *urerythrine*.

Further testing of Omicholic Acid, C, b.

To the ammoniacal solution barium chloride was added, with the view of producing an omicholate. An insignificant precipitate only was obtained, insufficient for analysis. The filtrate was rather dark coloured, showing that the barium had precipitated but little matter. The main bulk of the omicholic acid seemed to be precipitated by hydrochloric acid in light-brown flakes; but it was changed in its properties to the extent of being less soluble in ether and alcohol than before.

(*b.*) *Extraction by boiling Ether, and Examination of Products.*

The boiling ether seemed to extract more of the two bodies, which were separated as above. To the ammoniacal solution of omicholic acid, C, b, barium chloride was added, and the precipitate filtered off. It was washed with water until the filtrates were free from barium. The precipitate on the filter was next repeatedly washed with alcohol, when it was found that a quantity of uncombined omicholine had been left on the filter. During the precipitation of a barium compound, therefore, omicholine and omicholic acid had been precipitated from the ammoniacal solution. The salt, which remained insoluble in alcohol, was analysed.

1. 0·2369 grm. yielded 0·0715 $\cancel{Ba}\,\cancel{SO}_4$, equal to 17·74 % $\cancel{Ba}$. The residue contained a trace of iron, which was corrected in the following analysis:—

2. 0·1953 grm. yielded 0·0569 $\cancel{Ba}\,\cancel{SO}_4$ equal to 17·13 % $\cancel{Ba}$.

This barium compound therefore was shown to be an admixture of the omicholic acid, and not to contain any of this acid. As was proved more fully, omicholic acid does not combine with barium. It is therefore a sign of the purity of omicholic acid that its ammonia solution does not give a precipitate with barium chloride. Again, $\cancel{Ba}\,Cl_2$ is a means of purifying the ammoniacal solution of omicholic acid, particularly of that which has been obtained by means of cold ether, from another body.

Omicholine C, a, and omicholine C, b, were united, washed with pure water, and again dissolved in ether. They will in the following be designated as *omicholine C, a.*

The ammoniacal solution to which $\cancel{Ba}\,Cl_2$ had been added, omicholic acid C, a, and omicholic acid C, b, were united and treated with hydrochloric acid. A flaky precipitate fell down, which was washed, and in the following will be designated as *omicholic acid C, b.*

With these preparations the respective preparations from D. I. were united, because both had been obtained from the extract of urine by the mere addition of sulphuric acid without any boiling.

Elementary Composition of Omicholine C, a.

1. 0·3063 gms. dried at 85, (contained like all preparations of omicholic acid and omicholine in little boats of glass shaped for the purpose,) were burned in lead chromate, and gave 0·7859 $\cancel{C}O_2$ and 0·2962 $H_2\cancel{O}$ equal to 69·97 °/₀ $\cancel{C}$ and 10·74 °/₀ H. (The water contained a vestige of copper oxyde dust.)

2. 0·2863 gave 0·7275 $\cancel{C}O_2$ and 0·2458 $H_2\cancel{O}$ equal to 69·31 °/₀ $\cancel{C}$ and 9·54 °/₀ H.

3. 0·3193 gave 0·0746 $\cancel{P}t$ equal to 3·31 °/₀ N.

4. 0·2602 gave 0·0746 $\cancel{P}t$ equal to 4·06 °/₀ N.

Mean in 100.	Quotient by At. W.	Quot. by N = 1.
$\cancel{C}$ 69·64	5·8033	22·
H 10·14	10·1400	38·5
N 3·68	0·2628	1·
$\cancel{O}$ 16·54	1·0337	3·9

Leading to formula $\cancel{C}_{22}\ H_{38}\ N\ \cancel{O}_4$.

Elementary Composition of Omicholic Acid C, b.

Was brittle at 85° C., fused at 95°. Dried during 48 hrs. at 85°.

1. 0·1656 gms. burned with lead chromate and oxygen gave 0·3836 $\cancel{C}O_2$ and 0·1130 $H_2\cancel{O}$ equal to 63·17 °/₀ $\cancel{C}$ and 7·58 °/₀ H.

2. 0·2450 gms. burned with soda-lime, &c., gave 0·0845 gms. $\cancel{P}t$ equal to 4·89°/₀ N.

In 100.	Quot. by At. W.	Quot. by N.
$\cancel{C}$ 63·17	5·264	15·08
H 7·58	7·580	21·71
N 4·89	0·349	1·
$\cancel{O}$ 24·36	1·522	4·36

Formula $\cancel{C}_{15}\ H_{21}\ N\ \cancel{O}_4$.

Omicholine and Omicholic Acid D.

The ether extracts of preparation C. II. and D. II., D. III., D. IV., were united and treated together, as they had been obtained after boiling of the extract of urine with sulphuric acid. The residue was purified, and the substances separated as above described.

Elementary Analyses of Omicholine D, a.

1. 0·2770 burned with lead chromate gave 0·6732 $\cancel{C}O_2$ and 0·2030 $H_2\cancel{O}$ equal to 66·20 °/₀ $\cancel{C}$ and 8·14 °/₀ H.

2. 0·2043 burned with soda-lime, &c., gave 0·0536 $\cancel{P}t$ equal to 3·72 °/₀ N.

3. 0·1004 grm. gave 0·2240 Pt = 3·39 °/₀ N.

	In 100.	Quot: by At. W.	Quot. by N = 1.
C	66·20	5·516	21·80
H	8·14	8·140	32·17
N	3·55	0·253	1·
O	22·11	1·384	5·47

Formula = $C_{22} H_{32} N O_5$.

Elementary Analyses of Omicholic Acid D, b.

Of all the resins obtained this was the most liquid. Dried at 85° until constant—

1. 0·2534 burned with lead chromate, lastly with oxygen, gave 0·6050 CO_2 and 0·1865 H_2O equal to 65·11 °/₀ C and 8·17 °/₀ H.

2. 0·3062 burned as (1) gave 0·7261 CO_2 and 0·2344 H_2O, equal to 64·67 °/₀ C and 8·50 °/₀ H.

3. 0·2386 burned with soda-lime, &c., yielded 0·0856 Pt, equal to 5·08 °/₀ N.

4. 0·2644 burned do. gave 0·0979 Pt = 5·22 °/₀ N.

Mean in 100 parts.	Quot. by At W.	Quot. by N.
C 64·89	5·4075	14·70
H 8·335	8·3350	22·66
N 5·15	0·3678	1·00
O 21·63	1·3518	3·67

Formula $C_{15} H_{23} N O_3$.

Synopsis of Formulæ of Omicholine and Omicholic Acid according to preparations.

B, *a.*	$C_{24} H_{44} N O_6$
B, *b.*	$C_{16} H_{24} N O_4$
C, *a.*	$C_{22} H_{38} N O_4$
C, *b.*	$C_{15} H_{21} N O_4$
D, *a.*	$C_{22} H_{32} N O_5$
D, *b.*	$C_{15} H_{23} N O_3$

Synopsis and Mean of Formulæ of Omicholine.

B, *a.*	$C_{24} H_{44} N O_6$
C, *a.*	$C_{22} H_{38} N O_4$
D, *a.*	$C_{22} H_{32} N O_5$
Mean formula of omicholine	$C_{22} H_{38} N O_5$

Synopsis and Mean of Formulæ of Omicholic Acid.

B, *b.*	$C_{16} H_{24} N O_4$
C, *b.*	$C_{15} H_{21} N O_4$
D, *b.*	$C_{15} H_{23} N O_3$
Mean formula of omicholic acid	$C_{15} H_{22} N O_4$

Remarks.

Importance in kidney diseases.

These bodies are evidently well-defined different entities, although they have not yet been obtained in a pure state. They differ from each other, but cannot yet perhaps be absolutely separated from each other. On the other hand, they have so many properties in common, that the one may possibly be derived from the other, or that both may have a common origin. They are both obtained by boiling the watery solution of isolated urochrome with acid, and are therefore probably derivates of urochrome. Their molecular weight has not yet been determined, as no compound appeared definite enough for that purpose.

The importance of these bodies in pathology may be inferred from the fact that they are capable of forming in the human body in certain forms of kidney disease. The breath and the exhalation of the skin in such cases smell strongly of omicholine and omicholic acid. Their nauseous and emetic properties, already observed by Proust, may perhaps contribute to the explanation of that peculiar vomiting which occurs in cases of chronic kidney disease, in which dropsy and œdema have naturally, or by the constant use of the Turkish bath, ceased to be factors of the pathic process.

As it will, perhaps, be many years before (if ever) I can resume this research, and carry it to that completion which I strongly feel it wants, but which the time and materials at my command did not permit me to give it, I must hope that others will supply the desired information. They should extract the materials from several thousand gallons of urine in order to obtain quantity sufficient for all purposes. The quantity of omicholine and omicholic acid which can be obtained from lesser quantities of urine is indeed not small; but of the mixed resins obtained so much is lost in the various processes of purification, that what remains is the lesser portion, and insufficient for that varied analysation and testing which uncrystallisable and uncombinable substances more than any others require.

F.—*Uropittine.*

Synopsis of Preparations of Uropittine.

A. I.	Three elementary analyses. Uropittine perhaps a stage between urochrome and uromelanine.
A. II.	Meta-uropittine. Urorubine.
A. III.	From putrid urine. In store.
B. I.	
B. II.	
B. III.	
C. I.	Six preparations obtained, three from each, used and analysed as in special list.
C. II.	
D. I.	
D. II.	
D. III.	
D. IV.	Hypothetical silver-uropittate, from supposed uromelanine.

Uropittine, A. I. and A. II.

The uropittine described in the Hastings Prize Essay had yielded on analysis the

Mean in 100 parts.	Quot. by At. W.	Quot. by N = 1.
C 55·25	4·604	5·32
H 5·57	5·570	6·44
N 12·10	0·864	1·
O 27·08	1·687	1·952

If the latter quotients are multiplied by 7, the number of nitrogen atoms in uromelanine, we obtain uropittine = $C_{37}\ H_{45}\ N_7\ O_{11}$. From

this formula that of uromelanine could easily be derived by assuming that uropittine takes up two atoms of oxygen, and loses one molecule of carbonic anhydride and one molecule of water.

$$\underbrace{\mathfrak{C}_{37}\,H_{45}\,N_7\,\mathfrak{O}_{11}}_{\text{Uropittine.}} + \underbrace{2\mathfrak{O}}_{\text{Oxygen.}} = \underbrace{\mathfrak{C}_{36}\,H_{43}\,N_7\,\mathfrak{O}_{10}}_{\text{Uromelanine.}} + \underbrace{\mathfrak{C}\mathfrak{O}_2}_{\text{Carbonic acid.}} + \underbrace{H_2\,\mathfrak{O}}_{\text{Water.}}$$

In that case the atomic weight of uropittine would be 763.

It is unquestionable that the urochrome, as well during the chemolytic, as more particularly during the physiolytic process of decomposition, absorbs oxygen. During the operations accompanying the separation of uromelanine, much matter, soluble in alcohol and having the properties of uropittine, is gradually transformed into uromelanine. The above process may therefore express more than a speculative formula.

Meta-uropittine from Spec. A.

This body resembles uropittine in composition, but differs by being easily soluble in alcohol. It does not fuse in heat. After extraction of matters soluble in ether alcohol easily dissolved this matter. It was precipitated by water, washed and dried at 100° C. It was much less in quantity than urorubine, to be described below.

Analyses: 1. 0·3335 grm. burned in lead chromate gave $\mathfrak{C}\mathfrak{O}_2$ = 0·6554 or 53·59 °/₀ $\mathfrak{C}$ and $H_2\mathfrak{O}$ = 0·1947 or 6·48 °/₀ H.

2. 0·2645 grm. gave $\mathfrak{C}\mathfrak{O}_2$ = 0·5376 or 55·43 °/₀ $\mathfrak{C}$ and $H_2\mathfrak{O}$ = 0·1566 or 6·57 °/₀ H

	Mean of analyses.	Uropittine A. I. and II.
$\mathfrak{C}$	54·51	55·67
H	6·52	5·15

The substance therefore contains more hydrogen than the preparation from A. I. and II. by its side. Possibly it may be a substance which is yet before uropittine or urorubine in its transformation towards uromelanine. Its existence and empirical composition are here noted in order that future researches may refer to it and decide whether it is a transition product or a mixture.

Urorubine from Spec. A.

It had been separated from the uropittine described and analysed in the Hastings Prize Essay. It was easily soluble in cold absolute alcohol, and stood for three months in it to deposit body less soluble (Uropittine). It had then been precipitated by water, filtered and dried in vacuo. It was very hygroscopic, and after drying at 100°, when it did not fuse, always gained from two to three milligrammes under the dryer. After three days of labour the last weighing was assumed as practically correct.

Analyses: 1. 0·2448 grm. burned in chromate gave $\mathfrak{C}\mathfrak{O}_2$ = 0·5808 or 64·70 °/₀ $\mathfrak{C}$ and $H_2\mathfrak{O}$ = 0·1515 or 6·87 °/₀ H.

Deducting from the substance 0·0028 grm. of weight, which if it was not oxygen might possibly have been adventitious water, we get urorubine = 0·2420; $\mathfrak{C}\mathfrak{O}_2$ = 0·5808 or 65·45 °/₀ $\mathfrak{C}$ and $H_2\,\mathfrak{O}$ = 0·1487 or 6·82 °/₀ H.

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2. 0·2035 burned with chromate gave CO_2 = 0·4852 or 65·02 °/₀ C and H_2O = 0·1266 or 6·91 °/₀ H.

3. 0·3082 burned with soda-lime gave 0·2492 grm. Pt equal to 11·46 °/₀ N.

It is preferable not to assign a formula to this body at present. It contains more carbon than either uromelanine or uropittine, and could be considered as a body less oxydised than either of these two, and standing nearer to urochrome. It contains more than double the amount of nitrogen which is contained in omicholine or omicholic acid.

Hypothetical Silver-Uropittate from D. IV.—An ammoniacal extract from uromelanine D. IV. by evaporation and resolution in water was precipitated with silver nitrate, boiled, filtered, and washed with water. Washings were almost colourless, and free from silver. Dried in steam-closet, afterwards in air-bath at 110°,

(1.) 0·1501 burned left 0·0487, or 32·44 °/₀ Ag.
(2.) 0·1046 do. do. 0·0336, or 32·28 °/₀ Ag.

Thereupon another preparation was made in exactly the same manner, and yielded,

(3.) 0·1326 grm. left 0·0426, or 32·12 °/₀ Ag.

The salt was therefore surmised not to be a uromelanate, but to stand nearer to the uropittates with 38·71 (C, α, 3), and 35·49 °/₀ of Ag.

I look upon these and like analyses as merely tentative. When the same process applied to the same preparation yields the same compound, this constitutes a symptom in favour of the supposition that the compound is definite, *i.e.*, in atomic proportions. By producing a great many such compounds under varying conditions, those which conform to atomic laws are easily found out by their repetition. If instances remain isolated their accidental and non-specific nature is proved. I consider this proceeding the only one which in the present state of our knowledge of these matters can be applied for the obtaining of the precise information which is so urgently required.

Further Treatment of the mixed Resins C.

(*C.*) *Extraction with Alcohol.*

Cold alcohol extract.

The mixed resins, after having been exhausted, first with cold then with boiling ether, were treated with cold alcohol, and the dark solution was filtered. The filtrate (sol. α) after having stood some time had formed a deposit, and was therefore again filtered. A dark brown powder (designated as uropittine, specimen α, 1) remained on the filter.

Precipitate by ether.

The mother liquor (sol. α) was mixed with ether. It deposited a quantity of flaky light brown matter which after resolution in alcohol gave two specimens, which were designated specimens α, 2, and α, 3.

Hot alcohol extract.

The residue, which had been insoluble in cold alcohol, was now boiled with alcohol and filtered hot on steam funnel (solut. β) No deposit formed on cooling, but on first concentration a deposit, specimen β, 1, formed. On second concentration it deposited specimen β, 2. The mother liquor was evaporated to a syrup and mixed with five volumes of ether. It deposited a flaky light brown matter, β, 3.

Insoluble residue. Uromelanine.

After countless alcohol extractions there remained an insoluble residue (it imparted a colour to boiling alcohol, but the quantity dissolved was imponderable). It was dissolved in ammonia, precipitated by H_2SO_4, washed with water, treated with alcohol, dissolved in ammonia, and evaporated to dryness. By its properties, and the analysis

of a silver salt of it, it was found to be mainly *uromelanine*. For the watery extract of the dry residue (of which the greater part remained undissolved in the water, as is usual with uromelanine) on being treated with silver nitrate, boiled, filtered, and washed, gave the following results to analysis. Dried at 110°.

1. 0·1476 grm. left 0·0198 grm. or 13·41 °/₀ of Ag.
2. 0·1550 grm. left 0·0212 grm. or 13·67 °/₀ Ag.
3. 0·3458 grm. burned with soda-lime left 0·2662 Pt, equal to 10·91 °/₀ N.

Neutral silver uromelanine, C_{36} H_{40} Ag N_7 O_9 requires 13·13 °/₀ Ag, and yielded in the mean 13·47, which is almost the same as the foregoing mean 13·54 °/₀ Ag. Nitrogen required, if one H_2 O leaves the salt 11·92, found formerly 12·47. If no water leaves the neutral silver salt, it requires 11·66 °/₀ N.

Uropittine; Specimen C, α 1.

Ba salt.

The substance was dissolved in ammonia and the alkaline solution treated with Ba Cl_2. Precipitate washed and dried at 110° C.

0·1204 gave 0·0414 Ba SO_4, equal to 20·21 °/₀ Ba.

Note. Similar Ba salt obtained from omicholic acid.

Note.—A quantity of omicholic acid (Specimen B) in ammonia was treated with Ba Cl_2. After treatment like the precipitate from C, b, a compound was obtained, of which dried at 95°

0·3664 gave 0·1069 grm. Ba CO_3 equal to 20·28 °/₀ Ba.

This would therefore amount to a proof that omicholic acid, when it yields a precipitate with barium salts, contains uropittine. By the compound C, b, α, this proof was not definitely afforded.

It was also essayed to prepare a Ba salt from a neutral solution, but the quantity ultimately obtained was too small for analysis.

Uropittine Silver from Specimen C, α, 1.

Ag salt, 21·39 °/₀ Ag.

Uropittine (C, α, 1) dissolved in concentrated ammonia was evaporated to dryness. Of the residue a small part only dissolved in water, the greater part remained undissolved. Silver-nitrate was added and the mixture boiled. The precipitate was washed on the filter until the filtrates were free from silver and colourless.

1. 0·2412 grm. left 0·0510 grm. or 21·14 °/₀ Ag.
2. 0·1118 grm. left 0·0242 grm. or 21·64 °/₀ Ag.

Mean. 21·39 °/₀ Ag.

3. 0·1194 grm. burned in soda-lime, &c., gave 0·1033 Pt equal to 12·27 °/₀ N.

Bearing with Ammonia of Specimen C, α, 1.

The uropittine was dissolved in ammonia, the solution evaporated to complete dryness, and the salt redissolved in water. To the solution (a part remained undissolved) hydrochloric acid was added, whereby the uropittine was precipitated. The latter was collected, washed, and dried at 100° upon a weighed filter.

Dry uropittine = 0·1003 grm.

The acid filtrate yielded chloride of ammonium, which by the usual treatment left 0·081 grm. of Pt. This yields upon 100 uropittine 13·90 parts of ammonia, or in 100 parts of compound 87·8 uropittine and 11·20 °/₀ ammonia.

This is more than a molecule of ammonia for even a small formula of uropittine. Indeed as only a part retains ammonia, another becomes insoluble, the instability of the compound is proved. But it is interesting that even in a solution so treated there may be more than a quantity of ammonia necessary to produce a neutral salt. It must, however, not be forgotten that the quantities of material employed were very small.

Uropittine C, α, 2.

This substance was precipitated by ether from the solution in absolute alcohol of the mixed urinary resins. It was dried at 100°, and did not become soft.

1. 0·1596 grm. burned in lead chromate, ultimately in oxygen, yielded 0·3529 CO_2 and 0·0904 H_2O, equal to 60·30 °/₀ C, and 6·29 °/₀ H.

2. 0·2215 grm. burned in lead chromate without the employment of oxygen gave 0·4865 CO_2 and 0·1405 H_2O, equal to 59·90 °/₀ C and 7·04 °/₀ H.

3. 0·2346 grm. burned with soda-lime, &c., gave 0·1727 Pt, equal to 10·44 °/₀ N.

4. 0·2789 grm. burned, &c., gave 0·2066 grm. Pt, equal to 10·50 °/₀ N.

Synopsis of Analyses.

	1.	2.	3.	4.	Mean.
C	60·30	59·90	,,	,,	60·10
H	6·29	7·04	,,	,,	6·66
N	,,	,,	10·44	10·50	10·47
O	,,	,,	,,	,,	22·77
					100·00

Uropittine Silver.

From Prep. C, α, 3 (boiled preparation).

The specimen of uropittine used for the preparation of this salt was precipitated by ether from an alcoholic solution of mixed urinary resins. It was dissolved in ammonia. To the solution some more uropittine was added in order to ensure its neutrality; thereupon it was precipitated by silver nitrate. After having been boiled, a proceeding which was necessary to cause the immensely voluminous precipitate to contract, it was collected on a filter. It appeared of a dark green colour, while the mother liquor was slightly yellow. The washing liquors were of a darker colour than the mother liquor, and fluoresced strongly. Dried at 110°,

1. 0·2115 left 0·0818 grm. of Ag., or 38·67 °/₀.
2. 0·1837 left 0·0712 grm. or 38·75 °/₀.

Mean of these analyses is 38·71 °/₀.

This leads to 279 as the atomic weight of the salt, and 172 as the atomic weight of the organic residue (Ag. = 108). This is very near to the molecular weight of hippuric acid ($C_9 H_9 NO_3$) = 179; but it is not conceivable that this acid should be precipitated by ether, and be insoluble in water, except after having undergone great and peculiar alterations.

3. 0·3241 grm. burned with lead chromate gave 0·4340 CO_2 and 0·1164 H_2O, equal to 36·52 °/₀ C and 3·99 °/₀ H.

4. 0·2919 burned with soda-lime, &c., left 0·1430 grm. Pt, equal to 6·94 °/₀ N.

Synopsis of Analyses.

	1.	2.	3.	4.	Mean.
C	„	„	36·52	„	36·52
H	„	„	3·99	„	3·99
Ag	38·67	38·75	„	„	38·71
N	„	„	„	6·94	6·94
O	„	„	„	„	13·84
					100·00

Uropittine Silver. Second preparation from C, α, 3.
(Not boiled.)

Uropittine silver. Not boiled.

Uropittine obtained by ether from alcoholic solution of mixed resins, and purified by solution in ammonia and subsequent precipitation by hydrochloric acid, was again dissolved in a few drops of ammonia, and the solution made as neutral as possible by digesting it with an undissolved excess of uropittine. The filtered solution was precipitated by silver nitrate, and the precipitated silver-uropittate was collected on a filter and washed. The mother liquor and the filtrates were colourless. The precipitate was dried at 110° C.

1. 0·2150 grm. left 0·0770 grm. or 35·81 °/₀ Ag.
2. 0·2402 grm. left 0·0845 grm. or 35·17 °/₀ Ag.

Mean of these analyses 35·49 °/₀ Ag. leading to 304 as the Mol. W of the salt, and 197 as M. W. of uropittine.

3. 0·3144 burned with lead chromate left 0·4375 CO_2 and 0·1210 H_2O, equal to 37·95 °/₀ C and 4·29 °/₀ H.

4. 0·2708 burned with soda-lime, &c., left 0·1260 Pt, equal to 6·59 °/₀ N.

5. 0·2345 gave 0·1058 Pt, or 6·39 °/₀ N.

Synopsis of Analyses.

	1.	2.	3.	4.	5.	Mean.
C	—	„	37·95	„	„	37·95
H	—	„	4·29	„	„	4·29
Ag.	35·81	35·17	„	„	„	35·49
N	„	„	„	6·59	6·39	6·49
O	„	„	„	„	„	15·78
						100·00

The preceding shows that the former preparation was probably decomposed (oxydised) by the boiling of the precipitate. This effect i

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well known to occur in many silver-salts. It washazar ded in this instance because it had been found that the uromelanine-silver salts bear boiling without changing in composition.

Uropittine Barium.

Uropittine Barium, from C, α, 3.

It was attempted to produce a barium salt. The uropittine was obtained by precipitation with ether from an alcoholic solution of mixed urinary resins. It was dissolved in ammonia, and barium chloride added to the slightly ammoniacal solution. The mother liquor after filtration was dark coloured, but the washing water became constantly lighter, until it appeared only slightly yellowish at last. Although 0·5 grm. of uropittine had been dissolved, only 0·1605 grm. of barium salt were obtained.

Only analysis: 0·1605 grm. gave 0·0194 grm. $\mathfrak{B}a\ \mathfrak{S}\mathfrak{O}_4$, equal to 7·10 °/₀ $\mathfrak{B}a$.

Uropittine-barium is therefore not insoluble in water. However 7·10 is near 7·20 °/₀ $\mathfrak{B}a$, which was found in dibarytic penta-uromelanine ($\tilde{U}r_5\ \mathfrak{B}a_2$). Possibly, therefore, the uropittine might have contained thus much of uromelanine (still soluble in alcohol). It is, however, evident that from such extremely needy data no opinion can properly be formed.

Uropittine, Specimen C, β, 1.

$\mathfrak{C}a$ salt.

It was attempted to produce a neutral solution of this body by evaporation of its ammonia solution. By addition of $\mathfrak{C}a\ Cl_2$ was produced:

Uropittine Calcium.

Analyses: 1. 0·2069 grm. gave 0·0128 $\mathfrak{C}a\mathfrak{S}\mathfrak{O}_4$ equal to 1·81 °/₀ $\mathfrak{C}a$.
„ 2. 0·1944 grm. gave 0·0116 $\mathfrak{C}a\mathfrak{S}\mathfrak{O}_4$ equal to 1·75 °/₀ $\mathfrak{C}a$. Mean 1·78 °/₀ $\mathfrak{C}a$.
„ 3. 0·1840 grm. yielded 0·1578 grm. $\mathfrak{P}t$, equal to 12·16 °/₀ N.

If uropittine had a composition and atomic weight close to that of uromelanine, this compound might be considered as containing 3 $\tilde{U}r$: 1 $\mathfrak{C}a$. This compound would require 13·13 °/₀ of N. But if uropittine have a smaller molecular weight, the figures found for $\mathfrak{C}a$ lead to no acceptable formula. They show no parallelism to the $\mathfrak{B}a$ salts above described. A zinc salt 3 $\tilde{U}r$: 1 Zn. is amongst the compounds observed.

Uropittine, Specimen C, β, 2.

$\mathfrak{B}a$ salt from alkaline solution.

It was dissolved in a slight excess of ammonia, $\mathfrak{B}a\ Cl_2$ added, and dried at 110°.

0·2560 gave 0·0948 $\mathfrak{B}a\ \mathfrak{S}\mathfrak{O}_4$, equal to 21·77 °/₀ $\mathfrak{B}a$.

$\mathfrak{B}a$ salt from neutral solution.

A solution of uropittine in ammonia was evaporated to dryness, and the residue treated with water. A part dissolved an another remained insoluble. To the solution $\mathfrak{B}a\ Cl_2$ was added, which produced a flaky precipitate. This was collected on the filter and washed until the

filtrates were free from Ba. The last filtrates were slightly coloured but free from Ba. The bulky precipitate shrivelled to an insignificant amount during drying in the steam oven, and could not be separated from the paper sufficiently clean to be analysed.

Silver Compound of this preparation.

Ag. compound, 27·14 °/₀ Ag.

It was dissolved in ammonia and the solution evaporated to dryness. Of the residue only a small part dissolved in water, the rest remained insoluble. Silver-nitrate was added and the mixture boiled. The precipitate was washed upon the filter until the filtrates were colourless and free from silver. Dried at 110° C.

1. 0·1628 grm. left 0·0442 grm. or 27·14 °/₀ Ag.

The same Silver Compound obtained from another pure specimen of Uropittine, C, β, 3.

Same Ag. compound.

The uropittine had been precipitated by ether from an alcohol solution. It was dissolved in ammonia, evaporated, and precipitated by silver-nitrate. The washed precipitate, which had not been heated, was dried in vacuo over sulphuric acid, light being carefully excluded. It formed a glistening, blackish, violet brown mass.

0·346 grm. left 0·0937 grm. or 27·0 °/₀ Ag.

G.—*Researches on the Derivates of Hematocrystalline, the Colouring Matter of Blood, continued.—On Hematine, continued.*

Mode of obtaining from alcoholic blood-cake by tartaric acid.

a. A quantity of blood containing the colouring matter, which had been precipitated by alcohol, was mixed with carbonate of potash, and afterwards digested on a steam bath with a large proportion of alcohol. A deep red alkaline solution was obtained. To this an alcoholic solution of tartaric acid was gradually added, until the red precipitate at first thrown down redissolved to a certain extent. Thus the colouring matter was separated from the albuminous matters; the former was redissolved, the latter stained brown remained as a precipitate insoluble in the acid fluid. The liquid, which now consisted of an acid solution of hematine and some impurities, was evaporated at a temperature not exceeding 75° C. to about one-tenth of its bulk. A minute quantity of black crystals of microscopic dimensions separated on the liquid cooling, together with some fatty matters and small crystals of cholesterine. Various proceedings were adopted to purify the substance, but they failed to give the results required.

b, by oxalic acid.

b. The blood-cake was then pounded with oxalic acid, and the mixture digested with alcohol.

c, by sulphuric acid.

c. It was also extracted by means of alcohol and a little sulphuric acid.

Both proceedings *b* and *c* gave materials which were too impure to warrant further treatment.

d, by potash, tartaric acid, and alcohol.

d. Three gallons of blood were treated with seven times their bulk, *i.e.*, 21 gallons of a cold solution of potash carbonate, containing one part by weight of the salt in two parts of water. A thickish soup-like mixture resulted, which was filtered on square pieces of calico extended over a frame. The filtrate was not nearly colourless. The precipitate was tied up in the calico filters and pressed, gently at first, and more

tightly afterwards, until all the liquid was pressed out as much as possible. The compressed cakes were then treated with alcohol, and the carbonate of potash solution which separated on standing was poured off. The residue was then again well pressed, and now formed consistent cakes. These were crumbled and dried at the ordinary temperature by standing spread out in flat basins. This material was now triturated with warm absolute alcohol, and then digested with a large quantity of the same at a temperature not exceeding 40° C. The solution was filtered off and then treated with an absolute alcohol solution of tartaric acid. The potash was thus precipitated and the hematine remained dissolved. Enough acid was added to cause the liquid to show a decidedly acid reaction when the litmus paper first dipped into the alcohol was moistened with water. After about a third of the bulk of the liquid had been evaporated below 40° C, all the hematine was deposited on cooling in very minute bluish-black crystals. By further evaporation not much more hematine was gained, and what little deposited was exceedingly impure, resembling a brown fatty matter. This matter was soluble in alcohol, insoluble in water, was attacked by nitric acid and yielded a colourless solution.

Hematine crystals.

The hematine crystals were rhombic plates. They grouped themselves frequently with their edges upwards, so as to resemble clusters of needles. They were filtered off on a very close paper filter, washed with water and absolute alcohol. The microscope revealed the presence of slight traces of foreign matters, which it was determined to remove by recrystallisation.

H.—*Intermittent Hæmaturia, s. Hematinuria, s. Cruenturesis.*

Intermittent cruenturesis.

There is a rare form of disease, which has been described by a number of observers, but more particularly by Dr. E. H. Greenhow in a learned and instructive article in Edinb. Med. Journ., May 1868. He says that in all the cases which he has seen of this disease the attacks have been excited by the same cause, have taken the same form, exhibited the same general group of symptoms, and run the same definite course. The immediate exciting cause of the attacks has been invariably some definite exposure to cold or wet. The form taken by the attacks has been invariably that of paroxysms; these coming on suddenly, almost immediately after the chill was experienced, and passing off rapidly when the effects of the chill had been counteracted and the patient had become thoroughly warm. The general group of symptoms has been invariably the same, the additional ones occasionally exhibited being apparently due to an unusual degree of constitutional disturbance. In every instance the paroxysms have begun with coldness of the extremities, followed by general chilliness, amounting in the severer attacks to rigors. In like manner, in every case, the chilliness or shivering has been attended by a feeling of weight and pain in the loins, and by pain or a sense of weakness or stiffness in the lower limbs. The chilliness has been usually, though not always, followed by an imperfectly marked febrile hot stage. The patients have invariably passed, during the paroxysms, urine looking as if it were mixed with blood, and identical in general character. And lastly, the same definite course has been run by the paroxysms in every case. From half an hour to two hours after the chilliness or rigors the patient has never failed to pass the first dark-coloured urine, which has always been highly albuminous, and has contained numerous crystals of oxalate of lime, with more or less of brownish or yellowish red, amorphous granular matter,

and a few hyaline casts, but only occasionally some stray blood corpuscles. At each succeeding micturition after the chilliness, the urine has invariably shown more or less diminution of colour, of albumen, of oxalate of lime, and of its other abnormal constituents; resuming its natural character and appearance by the second or third micturition after slight attacks, and usually by the fourth or fifth after severer paroxysms. By the second day after an attack the patients, as a rule, have regained their ordinary degree of health and strength, and have continued well until some fresh exposure has brought on a new attack of their complaint. Most of the patients suffering from this disease have had the same pale, sallow, cachectic aspect, two of them having been distinctly jaundiced, and the others having all had at times an icteroid tint of skin.

Thus it appears that intermittent hematuria is a definite disease, due in all cases to the same remote constitutional cause. The only medical treatment which appears to have any effect in diminishing the liability to suffer from the paroxysms on every exposure, is treatment directed, during the intervals, towards the improvement of the general health and the strengthening of the patient's constitution. Once the paroxysms have set in, the most simple means of restoring warmth are all that it is advisable to use. The short duration of the paroxysms, the very general absence of blood corpuscles from the urine, even at the time of the paroxysms, and the complete recovery of the normal character of the urine within a few hours after their subsidence, seem to show that there can be no cause of hæmorrhage in the kidneys themselves, but rather that the disintegrated blood traverses through the walls of the blood vessels in the Malpighian bodies. For this reason Dr. Greenhow regards the kidneys rather as the organs of elimination than as the seat of the disease, and considers the renal irritation, the existence of which is manifested by the pain in the loins and by the presence of the casts, and occasionally also of stray blood corpuscles in the urine, to be a secondary affection consequent upon congestion of the kidneys produced by the sudden and unusual strain thrown upon them. Possibly the paroxysms may consist in the sudden disintegration of an unusually large quantity of blood corpuscles, setting free so considerable an amount of hemato-globuline that it cannot undergo the normal changes, but is eliminated through the kidneys in a comparatively unaltered state.

Amongst the English medical authors who have related cases of intermittent or paroxysmal hematuria, are, besides Dr. Greenhow, Sir Thomas Watson, Dr. Elliotson, Dr. Prout, and more recently Dr. G. Harley, Dr. Dickinson, and Dr. Gull. Several of these authors have considered the disease to be of malarious origin, and there is no doubt that in some of the cases published the patients had also suffered from ague. But on the other hand, not one of Dr. Greenhow's patients had suffered from ague, and some of them at least had never visited a malarious district. The same absence of malarious influence has been noted by Dr. Pavy and Dr. Murchison in cases published by them in the Pathological Transactions. The disease in fact merely resembles ague in its intermittent form, and in its commencement with rigors, which are followed, however, by only an imperfect hot stage and rarely by a sweating stage. It differs from ague in not being periodical, and in requiring, apparently, a fresh exposure to cold or damp to excite each separate paroxysm. The history of most of the cases seems clearly to indicate the existence, in all the patients, of some sort of dyscrasia, upon which the external chill acts only as the immediate exciting cause of the paroxysm. Many patients suffer from so-called rheumatic pains

APPENDIX.

No. 6. *On Chemical Identification of Disease, by Dr. Thudichum.*

Spectroscopical and chemical examination of the urine.

during the paroxysms. Some patients suffered from such pains at all times, but this was probably due to secondary syphilis with which they were afflicted at the same time. No post-mortem examination has ever been made of any case.

Spectroscopical and Chemical Examination of the Urine.—The urine, which had been kindly forwarded to me by Dr. Greenhow, was about an ounce and a half in quantity, of a brownish red colour, and turbid by a brownish red precipitate. This was filtered off, and by testing shown to be hematine in the same state as the hematine which is precipitated by acetic acid from a watery solution of blood on standing.

The filtrate was now more red than brown, clear, and port wine red in transmitted light. In a layer of $1\frac{3}{4}$ centimetres in thickness it had spectrum—

1. 39 to 49 = 10; int. 8; R. α.

Greenish yellow interval.

2. 56 to 65 = 9; int. 10; R. β.

Cut off at 68. The interval from 65 to 68 is shaded to intens. 3, and appears reddish.

In a layer of one centimetre in thickness the following spectrum was developed :—

1. 40 to 46 = 6; int. 4; R. α.
2. 57 „ 64 = 7; „ 3; „ β.
3. 72 „ 82 = 10; „ 5; „ γ.

Cut off from 87; though continuation seems to be illuminated.

Diluted + 1 water, 1 ctr. thick.

1. 41 to 47 = 6; int. 3; R. α.
2. 58 „ 64 = 6; „ 2; „ β.
3. 72 „ 82 = 10; „ 3; „ γ.
4. 88 „ 110 = 22; „ 5; „ δ.

Violet blue cut off at 141.

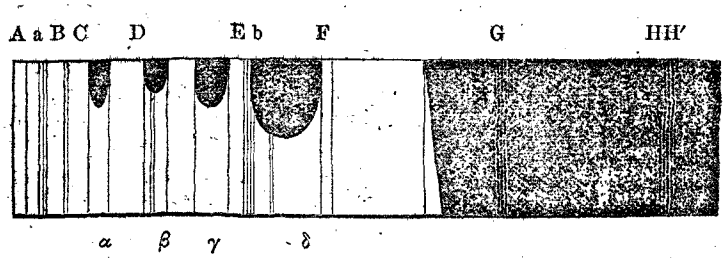


Diagram of Spectrum of Urine in Intermittent Hematuria.

At first sight this spectrum offered a remarkable similarity to that of cruentine described in the Appendix to the 10th Report. It was, however, clear from chemical reaction that cruentine could not be present. By boiling of the urine the entire amount of colouring matter was coagulated, and from the coagulum alcohol and sulphuric acid extracted hematine only. This pointed to hemato-crystalline, with the spectrum of which the bands β and γ nearly coincided.

The bands α and δ then appeared to coincide with two of the bands of hematine in acid solution. By measurement this was found to be nearly the case.

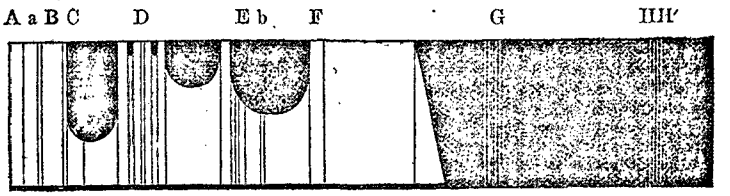


Diagram of Spectrum of Acid five-banded Hematine in Alcohol.

The urine was now treated with a reducing solution of sulphate of suboxide of iron in tartrate of ammonia with excess of this alkali, when the four bands immediately disappeared, and one broad band was present in their place.

1. 55 to 82 = 27. Int. 6.
Rest very dark. Cut off at 110.

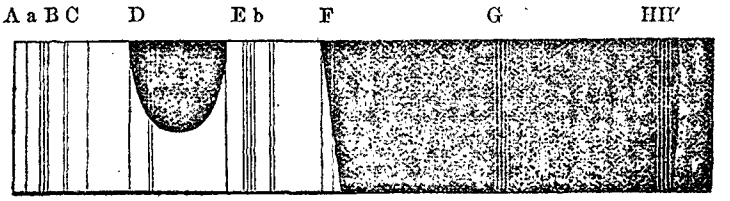


Diagram of Spectrum of Urine treated by reducing Fluid.

By violent shaking with air the broad band disappears, and the former bands do not reappear. The fluid is extremely turbid, and there remains even on dilution with water a very faint continuous spectrum without any bands. Nevertheless it is clear that the reaction of reduction indicates the presence of hematocrystalline as well as of hematine, as a comparison of the spectra of these substances in the reduced state with the spectrum just given will show.

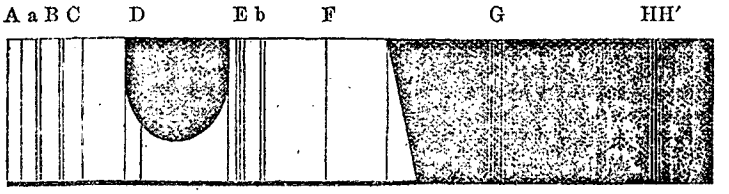


Diagram of Spectrum of reduced Hematocrystalline.

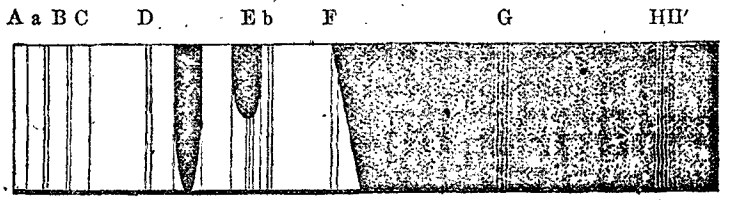


Diagram of Spectrum of reduced Hematine.

It will be seen from these spectra that the bands of reduced hematine and hematocrystalline necessarily coincide, so that the separation of the

bands of reduced hematine cannot appear, just as in the original spectrum of the urine the bands 2 and 3 of four-band hematine, or the bands 2, 3, and 4 of five-band hematine, coincide with the two bands of hematocrystalline. All facts therefore show that hematocrystalline and hematine in about equal proportions are present in the urine in question, and the only anomaly, which may perhaps yet be explained by the complex character of the fluid, is that on shaking with air of the reduced fluid, although the one band disappeared, none of the original bands reappeared. Somehow or other the substance had been changed by this operation.

The urine was extremely acid, and the excess of acidity seemed to be due to a volatile organic acid, probably *acetic*. On standing the urine gradually deposited a flocculent brown precipitate of hematine, and the bands of hematine in the spectrum became "pari passu" much paler, while the fluid became redder. The same bearing was observed in a mixture of watery blood with a little acetic acid. During my researches on cholera I also once observed an extract from muscle present the same spectrum as the above urine, but not having powerful light at my command I was unable to follow the observation in all its details. The extract from muscle also contained some acetic acid, and on comparison of the spectrum then observed and measured I have no doubt that it was due to the presence of a mixture of hematine and hematocrystalline (myochrome).

Conclusions.

These observations lead to the following conclusions :—

1. The urine in so-called paroxysmal hematuria contains hematocrystalline and hematine in solution. 2. The hematine also occurs as a precipitate which increases on standing. 3. There is no proof of the presence of dissolved albumen apart from the coagulable hematocrystalline (see, however, 5). 4. It is probable that in this disease a small quantity of blood is somehow or other dissolved, *e.g.*, by bursting of a Malpighian glomerulus, and mixing of the blood with effused urinary water, or by other means. 5. The hematocrystalline so effused is in part transformed into hematine (and some other body, possibly albumen, in a precipitated flocculent form), which for a time remains dissolved in the fluid, but is gradually deposited in the insoluble form. 6. This transformation is probably due to the morbid evolution in a certain part of the kidney of a quantity of organic acid, possibly acetic acid, which dissolves the hematine and imparts to the urine an unusual and very high morbid degree of acidity. 7. The presence of oxalate of lime in the urine is no great anomaly, but if it has any significance by being present in large quantity would point in the same direction as the presence of acetic acid. 8. Acetic acid by itself is also no anomaly, it being a normal ingredient of urine, as I shall show in an extensive research to be published on a future occasion. 9. But its presence in a concentrated form in a certain part of the kidney-tubes, where the other urinary constituents, notably urea, were not yet secreted and mixed with the hematocrystalline solution, so that it could transform a part of the effused hematocrystalline into hematine, is a great anomaly, and perhaps the essence of the disease. 10. Possibly the acid itself is the cause of the effusion of the blood, of its solution, and partial transformation.

I believe this to be the first instance in which hematine, hitherto known as an art-product of the laboratory only, has been proved to be present in an organic morbid fluid as the product of the diseased process itself. The name of "hematinuria" which has been proposed for the disease seems to me undesirable, because it would specify only one feature of the disease, and would unduly neglect the presence of hemato-

crystalline. Also "hematuria," being applicable to cases in which blood appears in corpuscles, does not appear to be a good denomination for the new disease. I would suggest "*cruenturesis*" (not cruentinuresis) as a suitable term; expressing the "*mictus cruentus*" without any attempt to define the particular coloured ingredients.

I.—*On Cruentine, continued.*

In the report for 1868, I described a series of new derivates of hematocrystalline under the name of *cruentine*, and distinguished the several bodies from each other principally by names derived from their spectral phenomena. All the bodies thus described had been extracted from the original cruentine sulphate by means of alcohol, and were therefore either sulphates, or neutral, or made alkaline after extraction. But their common property was that of being soluble in alcohol. This solvent, however, left a large quantity of the original sulphuric acid product undissolved, even after many extractions at the boiling heat. To this insoluble part the following inquiries were directed. It was found that the boiling alcohol solutions on cooling deposited also this peculiar cruentine, which by itself was insoluble in alcohol, even on boiling. It is therefore soluble in the boiling alcohol solutions of the acid cruentates, but not in the cold.

Two-banded cruentine.

Two-banded Cruentine.—The substance left insoluble by the alcohol was a gelatinous light-red matter, of great volume, as was ascertained by a drying experiment. It was soluble in sodium carbonate, and showed a spectrum of two bands—

1. 60 to 74 = 14; int. 4; R. α.
2. 78 „ 92 = 14; „ 3; „ β.

When precipitated from this solution, and treated with an excess of hydrochloric acid in much water, a red solution is obtained, which can be diluted to any extent without depositing the cruentine. This has spectrum—

1. 60 to 72 = 12; int. 3; R. α.
2. 77 „ 92 = 15; „ 2; „ β.

Blue to 153, where spectrum is cut off.

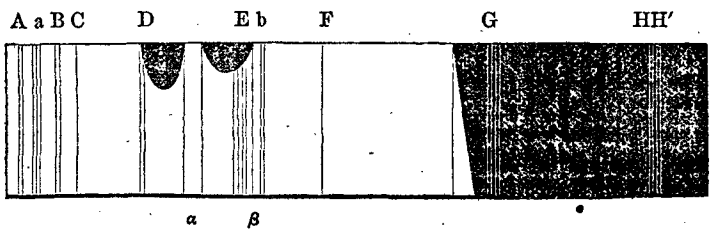


Diagram of Spectrum of Two-banded Cruentine in Hydrochloric Acid and Water.

This body has therefore intrinsically the same spectrum in alkaline as in acid solution, while all the other varieties of cruentine hitherto observed, as also hematine, change their spectra greatly when passing out of the alkaline into the acid state, or vice versâ.

APPENDIX.

No. 6.
On Chemical Identification of Disease, by Dr. Thudichum.

Effect of reducing agents.

Effect of reducing Agents.—By the addition of ammoniacal tartrate of iron suboxyde sulphate the band β is much weakened, and all but disappears, but the band α is not much influenced, particularly no change in its position effected.

Reactions of hydrochlorate of two-band cruentine.

Reactions of Hydrochlorate of Two-banded Cruentine.—The cruentine was dissolved in sodium carbonate, and filtered; it was then precipitated by hydrochloric acid, washed by decantation and redissolved in water acidulated with hydrochloric acid. It was allowed to stand, when a slight turbidity of fat rose to the top, and another portion subsided; it was then filtered, and the solution in sodium carbonate and dilute acid was repeated until the substance was steady and uniform.

$Pt\,Cl_4$.

Platinum tetrachloride produced a precipitate in the solution, which contracted on boiling and remained insoluble in boiling alcohol. *The precipitate had the spectrum of two bands just like the original solution.* The filtered mother liquor had no spectrum. The deposits from the second, third, and fourth boiling alcohol extract of cruentine sulphate were purified as above, and combined with platinum for analysis.

Analyses.—1. 0·4305 grm. dried at 120° to 130°, on burning left 0·046 grm. residue, from which hydrochloric acid extracted 0·002 grm. iron oxyde. Pt = 0·044 or 10·22 %.

2. 0·6625 of same preparation, left 0·075 residue, from which hydrochloric acid extracted 0·0055 grm. iron oxyde, Pt = 0·0695 grm., or 10·49 %.

The mean 10·35 Pt leads, if the small quantity of iron, amounting to less than 1 %, be neglected, to an atomic weight of 784. From a nucleus of this magnitude the molecular weight of uromelanine, 733, might easily be derived.

$Hg\,Cl_2$.

Mercury perchloride gave no precipitate even on boiling; the bands remained, and appeared remarkably like the blood spectrum. (It will be seen below that the solution by boiling for some time acquired the property of being completely precipitated by this salt.)

$Cd\,Cl_2$.

Cadmium chloride gave no precipitate, and the bands remained.

Cu acetate. Na and Zn acetate.

Copper acetate gave a precipitate containing all the cruentine; but as sodium acetate and zinc acetate also produce the complete precipitation of the cruentine, it is probable that acetates only act by displacing the solvent HCl, the free acetic acid being incapable of retaining the cruentine in solution.

$Fe_2\,Cl_6$.

Iron perchloride produces no precipitate, but intensifies the colour greatly, making it yellowish red.

NH_3.

Ammonia makes the pink solution dark red, and greatly intensifies the absorption of the spectral bands. In this ammoniacal solution—

$Ca\,Cl_2$. $Ba\,Cl_2$.

$Ca\,Cl_2$ and $Ba\,Cl_2$ produce precipitates on boiling, which are of light red colour, *and both show the two-band spectrum when exposed suspended in the fluid before the slit of the spectroscope.*

The barium compound was analysed:

(1.) 0·373 grm. left 0·0221 of residue, being barium-sulphate, and iron and copper oxyde, or 3·46 %. Of this 0·0170 was the amount of the latter oxydes, leaving $BaSO_4$ = 0·0051, consequently it contained less than 1 %, namely, only 0·8 % of Ba.

(2.) 0·6088 grm. left 0·0378 residue after treatment with H_2SO_4 = 3·64 %. Of this 0·0302 was iron and copper oxyde, leaving only

0·0076 $BaSO_4$, equal to 0·73 °/₀Ba. Mean of Ba found = 0·765 °/₀. This would lead to an atomic weight of 17908, which seems quite impossible. It is therefore clear that the Ba compound of two-banded cruentine decomposed during the washing with boiling water, to which the preparation, on account of its enormous bulk, had been subjected. Washing with cold water was found to be quite impracticable. The copper was derived from a copper still in which the alcoholic extraction had been made. The iron is a residue of that contained in the hematocrystalline.

A second preparation, washed once by filtration, lastly by repeated decantation, being too gelatinous to admit of washing on the filter, gave—

(1.) 1·6616 grm. (became heavier during heating to 120°) left 0·0992 residue.

(2.) 1·2136 left 0·0696 grm. residue. When the copper was discovered the analysis was not followed out any further.

KHO.

Dissolved in caustic potash and alcohol, with a little sodium carbonate added, and allowed to stand for a week, two-band cruentine assumes the following elegant property. *Itself being red it fluoresces light green;* it yields a beautiful light green, of a pure and lively tint, when influenced by the light-cone collected from the sun by a quartz collimator. It reminds much of the phenomena of *omicholine* and *omicholic acid.* It retains the two bands, but they are more feeble, particularly the second band is almost like that obtained by reducing agents. This spectrum reminds also of omicholine.

Effect of boiling upon cruentine hydrochlorate.

Effect of protracted boiling upon two-banded Cruentine Hydrochlorate.—The object of this process was to ascertain whether the iron could be removed from the cruentine or not. The solution was boiled three days long. After two days boiling the spectrum of the solution was unchanged, but black matter was continuously deposited. *The acid filtrate* from the dark matter on the third day was dark red, and *was completely precipitated by mercury perchloride.* (In a solution of two-band cruentine in HCl sublimate produced a precipitate which dissolved on boiling. On cooling the solution gelatinized completely. On violent shaking the flakes separated and left the liquid colourless. There is therefore a third variety of cruentine, and of behaviour with mercury perchloride.) The precipitate had a curious dirty grey colour, and no red or brown about it.

Reactions of filtrate $HgCl_2$.

Ferrocyanide of potassium.

Potassium ferrocyanide produced a copious complete precipitate in the filtrate, all matter being deposited of a dark dirty greenish colour. The solution contains apparently much free iron, as the fluid above the precipitate deposits a second *blue* precipitate, Prussian blue. Sulphocyanide gave a red precipitate. Consequently the hydrochloric acid extracts iron and a little organic matter, to which sulphocyanide adheres. But the insoluble residue contained iron in quantity (also copper, if such had been added to the solution).

The hydrochloric acid solutions filtered from the deposit, and all the washing waters, were repeatedly evaporated to dryness, and left a black residue. This dissolved in concentrated H_2SO_4, and with alcohol this solution gave spectrum of two-banded cruentine sulphate. The fluid was very opaque. The water solution with caustic potash gave spectrum of four-banded cruentine. It contained great quantities of iron (and the impure specimen alluded to also of copper).

The residue insoluble in HCl.

Cruentine made insoluble by boiling with Hydrochloric Acid.—The cruentine which had become insoluble in hydrochloric acid by boiling was washed with water. It remained insoluble in any kind of hydrochloric acid, concentrated or dilute, insoluble in ammonia, in alcohol, with or without acid or alkali. In its half-dried state it was, however, soluble in concentrated sulphuric acid. A mixture of a drop of this solution with alcohol gave the cruentine sulphate spectrum. The solution after standing 24 hours was poured into much water, and appeared almost completely precipitated. It was twice washed by decantation. The residue or deposit did not dissolve in concentrated or dilute hydrochloric acid, even on boiling, but dissolved easily in alcohol and a little HCl. It did not assume the two-band hydrochlorate spectrum of cruentine, but showed the sulphate spectrum—

1. 52 to 58 = 6
2. 61 „ 77 = 16

[Similarly a decoction with HCl of the precipitate from an alkaline solution of total cruentine (four-banded) which had been boiled during many weeks daily, showed not the two-banded hydrochlorate spectrum, but the sulphate with the narrow and wide band, the same as the foregoing. See measurements below.]

The addition of ammonia to the alcohol solution produced the *four-band cruentine spectrum.* A slight precipitate ensued in the solution which was probably an insoluble modification of the four-banded body.

Alcohol and HCl and dried two-banded cruentine.

Effect of Alcohol and Hydrochloric Acid upon dried Two-banded Cruentine.—The cruentine sulphate as before was boiled with alcohol to exhaustion, until nothing but the light red two-band cruentine, quite insoluble in alcohol on boiling, remained. This was dried and shrunk to a brownish red matter. It was slowly soluble in concentrated sulphuric acid on trituration and standing, and precipitated by water. It was also soluble in ammonia, but was partly deposited from this solution on standing by the evaporation of ammonia. (See *spectrum of deposit, below.*) It dissolved best in hydrochloric acid and alcohol, and the solution had the spectrum of cruentine sulphate.

1. 54 to 59 = 5 ; int. 1 ; R. β
2. 62 „ 79 = 17 ; „ 5 ; „ α

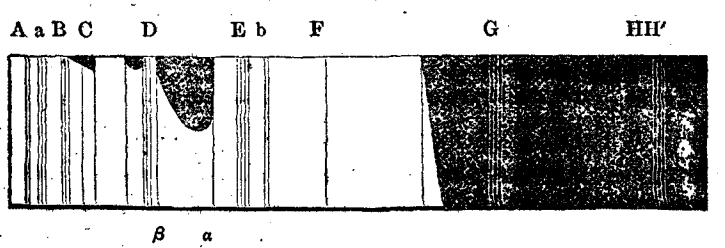


Diagram of the Spectrum of this Hydrochloric Alcohol Solution of Cruentine.

The greatest intensity of α is midway between 68 and 79, end at 142. The red is rather suddenly cut off, as if there was a band from 37 to 44. The foregoing spectrum is therefore identical with that of the hydrochloric product of cruentine described on p. 231 of Report, 1868. But there was this difference, that the solution after addition of ammonia

became *red when concentrated, green when diluted, and changed spectrum.*

1. 50 to 67 = 17; Int. 5; R. α
2. 75 „ 85 = 10; „ 1; „ β

Cut off at 110.

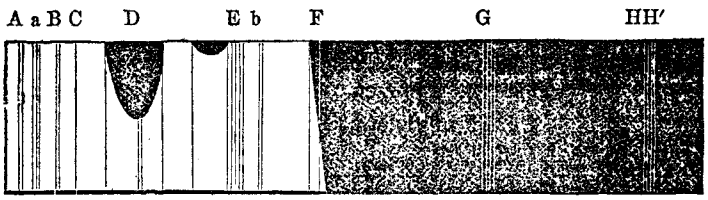


Diagram of Spectrum of Ammonia Solution of foregoing Body.

By reference forward it will be seen that this spectrum though similar to is not identical with the spectrum of two-banded cruentine hydrochlorate in water. When this latter solution is, however, made alkaline with ammonia it shows spectrum—

1. 54 to 68 = 14; Int. 5; R. α
2. 72 „ 84 = 12; „ 2; „ β

Cut off at 112.

Thus it is seen that this spectrum stands midway between the spectrum of acid watery and the ammoniacal alcohol solution.

Deposit from ammonia.

Deposit from Ammonia Solution of Two-banded Cruentine.—This deposit, which was obtained as above described, was redissolved in concentrated ammonia. It showed a spectrum of certainly four, possibly five bands, distributed as follows:

Band in red questionable.

1. 54 to 63 = 9; Int. 2; R. γ
2. 69 „ 77 = 8; „ 2; „ β
3. 85 „ 99 = 14; „ 3; „ α
4. 113 „ 127 = 14; „ 1; „ δ

Band No. 4 is in blue to indigo.

Cut off at 143.

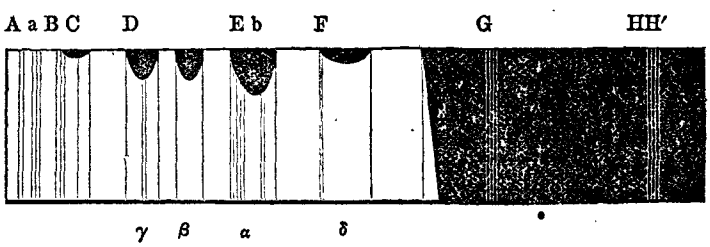


Diagram of Spectrum of Ammonia Solution of Deposit from Ammonia Solution of Two-banded Cruentine.

In case this experience should be repeated the red part of the spectrum will have to be examined in thicker layers of fluid. The band 4 or δ is quite peculiar to this body, no band having hitherto been found so far in blue with any preparation of cruentine.

Two-banded cruentine and hydrothion.

Two-banded Cruentine and Sulphuretted Hydrogen.—Cruentine was precipitated by soda from HCl solution and washed. It was then dis-

solved in ammonia and the solution treated with hydrothion. It became very black coloured. On continued boiling it deposited all coloured matter together with black granules. Ammonia redissolved only a small portion, which had the same two bands as before. Even concentrated ammonia dissolved very little. Consequently the hydrothion had so far changed the cruentine as to make it insoluble in watery ammonia. The changed cruentine was, however, soluble in ammonia and alcohol, and formed a splendid red solution, which gave spectrum—

1. 63 to 74 = 11; int. 4; greatest on violet side; R = α
2. 80 „ 93 = 13; „ 2; even „ = β.

Cut off in violet at 150.

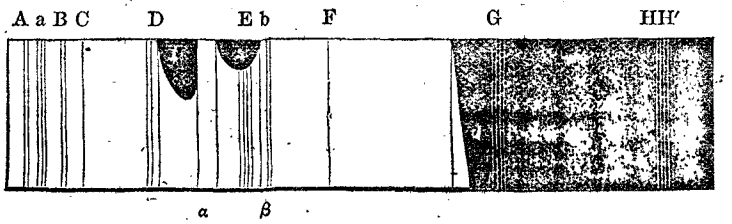


Diagram of Spectrum of Alcohol and Ammonia Solution of Two-banded Cruentine changed by Hydrothion.

On standing the dissolved matter became completely precipitated, and the alcohol almost colourless by loss of NH_3. The addition of a little NH_3 restored perfect solution. But after it had stood for one day the red matter had lost its solubility in alcohol with or without ammonia. Even boiling with these agents extracted only traces of matter, the iron had not been removed by the hydrothion. Concentrated sulphuric acid redissolved the matter and transformed it again into cruentine sulphate. This had the now well-known two bands in alcohol, but its watery solution treated with ammonia gave a precipitate, and after that was filtered off the solution showed spectrum of four-band-cruentine.

Concentrated H_2SO_4 and cruentine.

Effect of concentrated Sulphuric Acid upon Cruentine.—Cruentine had been dissolved frequently in concentrated sulphuric acid, it was at last dark brown. By frequent extraction with boiling alcohol of the precipitated and washed matter a soluble portion was extracted. The insoluble portion was dissolved in NH_3, filtered, evaporated to dryness, dried, and burned, and residue determined.

0·374 grm. product from cruentine dried at 125° left 0·019 Fe_2O_3, equal to 3·5 °/₀ Fe.

Alcoholic extract.

The alcoholic extract had a peculiar spectrum:

1. A broad feeble band. 49 to 74 = 25; int. 2; R. α

Blue shaded from 78 to 112, where the spectrum is cut off.

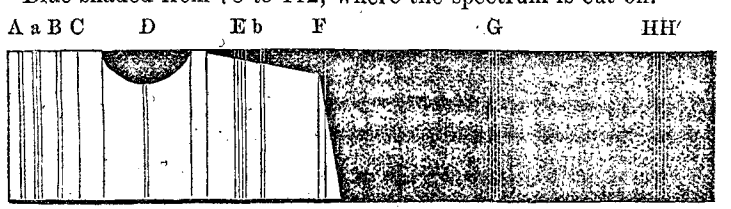


Diagram of the Spectrum of this Alcohol Solution.

The entire spectrum is very shady, though the red solution is quite clear. On dilution the band disappears before the shading in blue, and

the spectrum now reaches to 155. Diluted the red solution becomes brown; though still perfectly translucent it fluoresces with a smoky hue in diffuse sunlight; in the cone of the collimator it fluoresces strongly *in white with a tinge of greenish brown.* It differs completely from the fluorescent cruentine formerly described which becomes *red,* and shows the phenomena in a much feebler degree. The fluorescent body can in its power be compared only to solution of orchil (cudbear). The alcohol was evaporated, the residue dissolved in NH_3, filtered, evaporated, and the residue burned. It left red iron oxyde, which was almost insoluble in HCl.

Fluorescence.

It was thus shown that cruentine cannot be deprived of iron by treatment with concentrated sulphuric acid and precipitation with water, even if continued so often that only enough material for one analysis is left. I believe that Lehmann never succeeded in obtaining hematine quite free from iron by this method, and I have never succeeded myself. I therefore believe that the statements of Mulder regarding hematine free from iron are as fallacious as his ideas regarding proteine free from sulphur. I found even that when copper salts or tin salts are mixed with cruentine, these metals follow the cruentine through all changes, and though a little may be lost at each change, there is always a quantity remaining in the ultimate cruentine.

Conclusions.

Hematomelanine.—Thus I term the last product of the influence of sulphuric acid upon hematocrystalline and cruentine. It is purified by solution in ammonia, evaporation to dryness, and washing with water and alcohol. It is a black, shining matter, and burns with fusing and swelling, giving out much carbonaceous gas, which burns with strong yellow flame, greatly differing from the burning of uromelanine. It leaves a residue of iron oxyde.

Hematomelanine.

Influence of Carbonate of Sodium and boiling upon Cruentine.—The crude cruentine was dissolved in sodium carbonate and boiled for two days. After that it showed spectrum—

Influence of sodium carbonate and boiling.

1. in red, feeble, 40 to 51 = 11 ; Int. 1.
2. in yellow, 57 „ 71 = 14 ; „ 3.
3. in green, 76 „ 89 = 13 ; „ 5.

then darkness. More diluted the first band disappeared entirely, and there appeared band

4. 93 to 106 = 133 ; Int. 3.

The earlier alcohol extracts formerly described measured in spectrum—

1. 45 to 54 ; Int. 1.
2. 63 „ 75 ; „ 3.
3. 79 „ 92 ; „ 4.
4. 98 „ 115 ; „ 3.

The soda had therefore hardly changed the cruentine.

After having been boiled daily during four weeks the spectral phenomena remained as above. It was precipitated by HCl and washed by decantation, during which it began to smell disagreeably, the weather being very hot. Treated with HCl in excess only a small portion of the substance dissolved, yielding apparently the cruentine sulphate spectrum (see below), not the two-banded hydrochlorate. Like another specimen which, boiled with HCl, smelled of glue and gelatinised, so this smelled of spoiled glue. The insoluble residue easily dissolved in alcohol, yielding four-band spectrum, feebly by itself, more strongly and better defined after addition of NH_3.

The circumstance that the sulphate spectrum was obtained instead of the hydrochlorate caused me to examine for sulphuric acid. The solu-

tion was mixed with $BaCl_2$ and HNO_3, and allowed to stand two days, when a trace of barium sulphate had deposited. But the spectrum was apparently the same as before, only the first narrow band seemed much paler.

1. 49 to 58 = 9; Int. 1; R. β.
2. 61 „ 77 = 16; „ 5; „ α. The maximum of intensity is not in the middle, but has its axis at 73. Cut off in blue at 154.

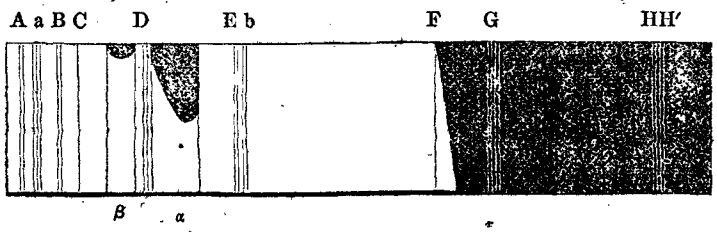


Diagram of this Spectrum of Cruentine Hydrochlorate in Alcohol.

Perhaps there is a shade, a slight indication of a band in green from 84 to 93. Before the addition of the barium and nitric acid the HCl solution measured—

1. 51 to 58 = 7; Int. 1; R. = β.
2. 61 „ 77 = 16; „ 3; „ = α.

Consequently the bands are the same in situation, but changed a little in relative intensity, the difference being greatest in the solution from which H_2SO_4 was removed. *Consequently this body is not a sulphate, although its spectrum is almost identical with that of cruentine sulphate.*

Residue.

The residue on filter from first HCl decoction was again treated with HCl, and found soluble in alcohol. It had the same bands as the above solution, but being more concentrated the whole spectrum was more obscure. *A special obscuration in red* reached from 34 to 47. Addition of NH_3 produced the four-banded alkaline cruentine.

1. 44 to 48 = 4; Int. 1.
2. 52 „ 68 = 16; „ 3. Greatest or axis intensity of this band at 64.
3. 71 „ 85 = 14; „ 4.
4. 88 „ 105 = 17; „ 5.

There ensued a precipitate in the solution. After filtration the spectrum was lighter, but the absorption also less intense. It is therefore possible that both the soluble and insoluble part were four-banded cruentine.

Action of soda, &c., upon cruentine.

Action of Soda, Hydrochloric Acid, and Ammonia upon Cruentine.—The crude or total cruentine was as in the foregoing experiment boiled for weeks with soda, afterwards dissolved in hydrochloric acid and boiled; the insoluble part was filtered from the solution, and the latter mixed with alcohol. This showed most distinctly the band in red which had been surmised to exist in the previous observation.

1. 35 to 46 = 11; Int. 2; R. α.

Shading commences at 51. More diluted there appeared—

2. 60 to 84 = 24; Int. 2.
3. 90 „ 107 = 17; „ 1. (Very difficult to determine.) End at 125.

This, therefore, is the second hydrochloric acid product described

on p. 232 of Rep. of 1868, but it differs in the intensity of its absorption.

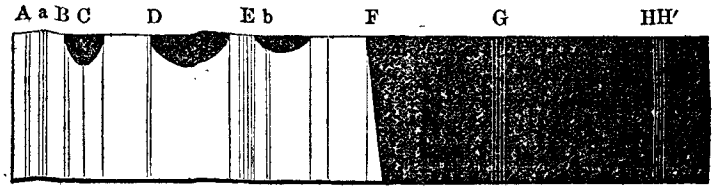
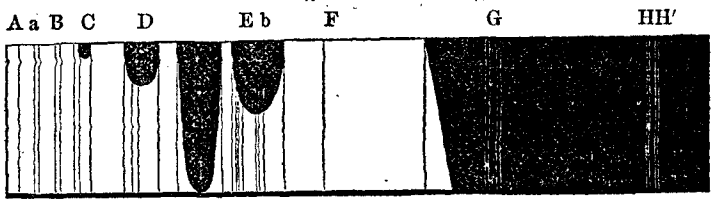


Diagram of the Hydrochlorate of Cruentine described in the foregoing.

Treated with excess of ammonia this body assumed the spectrum of the alkaline four-band cruentine represented on p. 229 of Rep. 1868, first diagram.

1. 44 to	49 =	5 ;	Int.	1.
2. 53 „	69 =	16 ;	„	2.
3. 73 „	85 =	12 ;	„	3.
4. 89 „	105 =	16 ;	„	3.



The part which had become precipitated in the HCl solution after resolution in soda carbonate, also showed the four-band spectrum.

Cruentine and nitric acid.

Cruentine and Nitric Acid.—Solid cruentine as it came from the sulphuric acid process, containing yet $H_2 SO_4$, was dissolved in hot nitric acid, and heated until no more red vapours were evolved; it formed a yellow thick solution of an aromatic smell. Addition of water precipitated a yellowish green matter, which became darker by exposure, and shrunk much during drying. The dried matter was only partially soluble in alcohol of 80 °/₀; more dissolved on boiling, and was deposited on cooling. The alcoholic solution after neutralization with ammonia gave a precipitate with silver nitrate, which became darker on standing.

Precipitate by Ag.

The precipitate by water was soluble in ammonia, and this solution gave precipitates with $Ca Cl_2$ and $Ba Cl_2$, which were yellow, the solution remaining strongly yellow. The acid water from which the flakes had been precipitated was evaporated to dryness, and again mixed with water. Then brown resinous drops were deposited which did not solidify on standing for some days; consequently several bodies are formed under the influence of nitric acid. (1.) A yellow body soluble in alcohol, nitrocruentine. (2.) (3.) Two yellow bodies insoluble in alcohol on boiling. The mixture was treated with ammonia, which dissolved one portion, namely, the body (2), or nitrocruentic acid, and left (3) nitrocruorine. This on boiling with water, and repeated addition of ammonia, swelled, but did not dissolve; on attempted filtration it speedily clogged the filter. (4.) Brown resinous drops. (5.) The watery acid solution containing probably oxalic acid and a yellow product. Neutralised with baryta water and barium carbonate it yielded a yellow neutral filtrate, which on evaporation became darker every moment, and ended as a completely decomposed brown, hard, blistery mass. It had been treated exclusively on the steam-bath, where a higher temperature than 90° to 95° could not be attained.

Brown semi-fluid resin.

J.—*A peculiar Reaction of Cod-liver Oil, and a similar Reaction of Fatty Matter from Fibrine of Blood.*

a.) When cod-liver oil is treated with concentrated sulphuric acid it immediately yields a purple reaction. The mixture cannot well be diluted with more oil, as in that case it becomes turbid, but on dilution with concentrated sulphuric acid a beautiful purple liquid is obtained. This when examined before the spectroscope with Drummond's light, allows red, yellow, and green to pass up to 74. On great dilution with acid the absorption recedes towards violet. When blue begins to appear, green is perfectly clear. The acid solution fluoresces green, and on further dilution becomes yellowish brown.

The addition of a trace of sugar to the cod oil greatly intensifies the reaction, and causes it to remain red on dilution with acid, and not to become yellow so quickly as otherwise. This mixture yields the following spectrum :—

Band 73 to 100, when dilute. Intens. 1 ; or 73 to 110, when more concentrated.

At the end there is a lavender coloured band up to 145, where spectrum ends.

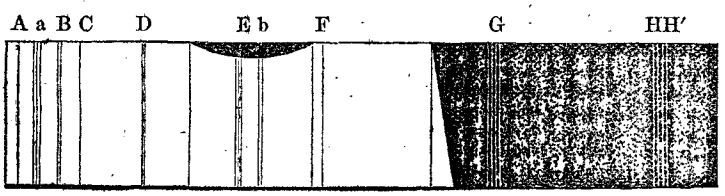


Diagram of Spectrum of Reaction of Cod-liver Oil with Sulphuric Acid and Sugar.

b.) A large quantity of fibrine which had been most carefully washed was dissolved in dilute sulphuric acid. On standing a scum collected on the top, which was washed by repeated decantation, ultimately on the filter. Gradually after the last filtrates, when the paper had become dry and the temperature of the air become high, some *fluid oil* percolated which had the following properties :—It was colourless. With sulphuric acid it immediately gave the red test for cerebric acid. With sulphuric acid and sugar it gave the purple test, and on standing two days gelatinised in a curious manner and became black. The *alcohol extract* from this was red, and showed the following spectrum :—

Red, yellow, and green to 75, then dark to end.

On cautious further dilution a feeble band becomes isolated—

80 to 113 = 33. Intens. 1.

After which there is a beautiful violet band to the end at 146.

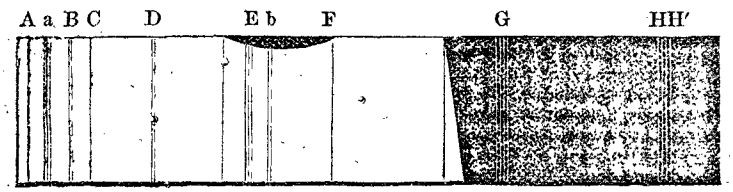


Diagram of Spectrum of Reaction of Fibrine Oil with Sulphuric Acid and Sugar, extracted by Alcohol.

More diluted absorption remains, 87 to 113 = 32. Violet gets more blue and extends to 166, when absorption disappears.

When describing the ingredients of the corpora lutea of cows, I gave a peculiar reaction which their juice, obtained by heat, yields with sulphuric acid and sugar. The mixture became purple, and its spectrum showed a band in green.

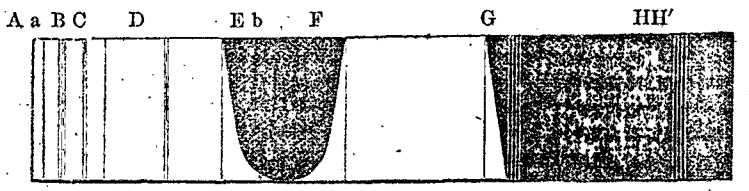


Diagram of Purple Test of Juice of Corpora Lutea.

76 to 113 = 37. Intens. 10. Cut off at 155.

Cod-liver oil gave spectrum—

73 to 110 = 37. Intens. 1. End 145.

Fibrine oil gave spectrum—

80 to 113 = 33. Intens. 1. End at 146.

These spectra are so very similar to each other that they may be due to one and the same body, which we may assume to be an ingredient of all three animal liquids employed. The greatest difference is exhibited by the spectrum of the juice of the corpora lutea, which has an intensity of 10, while the other bodies are much less intense, remaining about 1. This may be due to the circumstance that the juice contains much more of the substance yielding the reaction than the two oils.

The spectra which cod oil and fibrine oil yield when treated with sulphuric acid only, without any sugar, give the same continuous absorption in blue and violet, and are therefore identical.

All solutions show a slightly green fluorescence, those with acid only most conspicuously, those with sugar least. From the foregoing we may draw the following conclusions :—

1. Cod-liver oil, fibrine oil, and the juice of corpora lutea contain each a peculiar substance, the particular chemical properties of which are similar in all three mixtures.

2. The colour test of these substances is apparently identical with the test which cerebric acid, lecithine, and biliary acids yield with the same reagents. Spectrum analysis shows, however, that the test of cerebric acid and lecithine with sulphuric acid alone exhibit absorption bands, while the three matters under examination do not show absorption bands under the same circumstances.

3. The reaction of biliary acids with sulphuric acid and sugar (Pettenkofer's test) yields a spectrum with three bands, one band overlying the D line. (See p. 256 of last Report.) The same reaction with cerebric acid yields a spectrum with a band in green midway between D and E; but with the substance in the three bodies the same reaction gives a spectrum with a band which reaches from midway between D and E to nearly F, and which is therefore not only moved more towards the violet end but also much broader.

4. I think it probable that the substance in cod-liver oil is derived from the liver-cells, that in fibrine from white blood corpuscles entangled in the fibrine, and that in the juice of corpora lutea from the peculiar cells of those bodies.

APPENDIX.

No. 6. *On Chemical Identification of Disease, by Dr. Thudichum.*

K.—*Chronic Yellow Atrophy of the Liver, or Malignant Jaundice.*

Notes of case.

The subject of this disease was a man about 45 years of age, who had gradually become jaundiced. There was no history of gallstones, and the colour of the fæces indicated a diminution only, not a complete arrest, of the excretion of bile. The patient had fever, and was dropsical, the ascites being considerable. The liver on percussion was found much reduced; the fluid in the abdomen, however, made the exact determination of its limits difficult.

Characters of urine.

The first urine examined amounted to 200 CC, and was very bilious, yielding the test for bile-acids with sulphuric acid and sugar, for cholophæine with nitric acid, and, as was supposed, for tyroine with nitrate of mercury containing subnitrite. It contained a little albumen. It was filtered and precipitated with lead acetate, heated, filtered, and washed. The filtrate was evaporated to small bulk and treated with alcohol. A precipitate ensued. This was filtered off and washed with alcohol, and then extracted with concentrated ammonia. It was then boiled with water, which extracted much matter and left a little xanthine undissolved. The solutions gave a white precipitate with mercury nitrate, and no red colour with nitrite, thus showing that tyroine was *not* present.

The solution in water was evaporated and left a colourless amorphous residue. This dissolved easily in nitric acid without effervescence or red vapours, and on drying at a gentle heat a purple residue remained, which became bluish-purple with caustic potash. Concentrated hydrochloric acid dissolved a portion, and crystals formed on evaporation, which did not polarize, consequently were not uric acid. On boiling in a little water these crystals left again amorphous matter which became insoluble.

Xanthine and hypoxanthine.

We have therefore probably both *xanthine* and *hypoxanthine* in this water extract. The first residue, insoluble in water, was certainly xanthine, and the second matter may have been hypoxanthine, although the circumstance that it gradually became insoluble also points towards xanthine; for it is a well-established property of xanthine to become more and more insoluble in water the more frequently it is dissolved in or treated with it.

Volatile aromatic oil.

The reaction which simulated the presence of tyroine was probably due to the volatile aromatic oil present in every urine, and which I have first described in the Hastings Prize Essay; but this must certainly have been present in great excess before it could give so intense a reaction. Thus far, therefore, there were only biliary matters as abnormal ingredients; the other isolated bodies were normal.

The urine of the second day of observation was 630 CC, strongly yellow; after filtration in bulk greenish brown. The filter remained yellowish red, as if stained by cholophæine. It was precipitated with lead acetate, the filtrate treated hot with hydrothion and filtered.

Peculiar crystals.

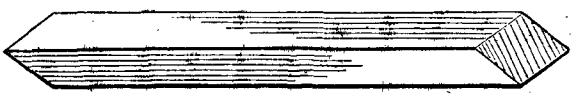
On standing 36 hours it deposited a mass of peculiar filmy crystalline needles. They were isolated, the mother liquor further evaporated, and allowed to stand.

In the same manner the urine of ten consecutive days was treated, and the crystals obtained were united. On examination they were found to be a particular new form of uric acid, which may be called

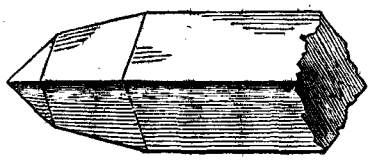
Para-uric acid.

para-uric acid. This substance is similar to xanthine by its reaction with nitric acid, and by the behaviour of its nitrate of silver compound when dissolved in nitric acid. It is similar to hypoxanthine or sarkine in its crystallised form, solubility in water, and deposition from boiling water, and in the reaction with nitric acid. But it differs from hypoxanthine in this, that its silver nitrate compound is easily soluble in nitric acid, and not easily deposited on cooling, while hypoxanthine silver

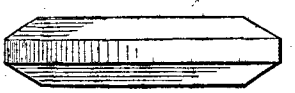
nitrate is completely deposited. It differs from both xanthine and hypoxanthine in this, that its watery hot solution, when precipitated by silver nitrate, yields a compound, which, when freed from all excess of silver, dissolves easily in nitric acid with effervescence, and deposits nothing on cooling. After much evaporation, however, and cooling, it deposits nitrate of silver, thus showing that in the nitric acid solution the nitrate of silver and nitrate of para-uric acid are not combined. The mixture of nitrate of silver crystals and para-uric acid nitrate, after re-solution in water, yields a copious precipitate with ammonia, which, bulky at first, contracts in excess. This is similar to both xanthine and hypoxanthine. It differs from both in this, that it dissolves in dilute nitric acid under evolution of carbonic acid. The solution on evaporation leaves a purple residue. Para-uric acid differs from uric acid by its solubility in water, and greater solubility in hot water, forming a crystallised deposit; by its peculiar shape of crystals, which are needles of long rhombic prisms with complicated ends, being a combination of two rhombic octahedra; and by its saturated solution in cold water on addition



of hydrochloric acid immediately depositing fine lustrous crystals, which under the microscope have this shape. Para-uric acid is, however,



similar to ordinary uric acid by its insolubility in cold, slight solubility in boiling concentrated hydrochloric acid; by its solubility under evolution



of carbonic acid (and nitrogen?) in dilute nitric acid, and by the purple-coloured residue of this solution on evaporation to dryness.

Biliary colouring matter.

The lead precipitate after washing was suspended in alcohol and decomposed by hydrothion. The filtrate was allowed to evaporate spontaneously. A greenish yellow residue remained, which was entirely soluble in water, and against expectation did not give the nitric acid test of cholophæine. This substance or its derivate had therefore been lost or changed during the chemical process for its isolation.

Results.

Results.—The nitrate of mercury test applied to urine directly may indicate tyroine when none is present. The reaction is due to the essential oil. The urine in chronic malignant jaundice contains biliary matters, and an anomalous acid of the uric acid group, to which the name of para-uric acid has been given. It does not contain tyroine or leucine, bodies which are often present in the acute form of the disease.

APPENDIX.

No. 6.
On Chemical Identification of Disease, by Dr. Thudichum.

L.—*On a peculiar Reaction of Lecithine from Yelks of Eggs with Sulphuric Acid, and on primary and secondary Absorption Spectra.*

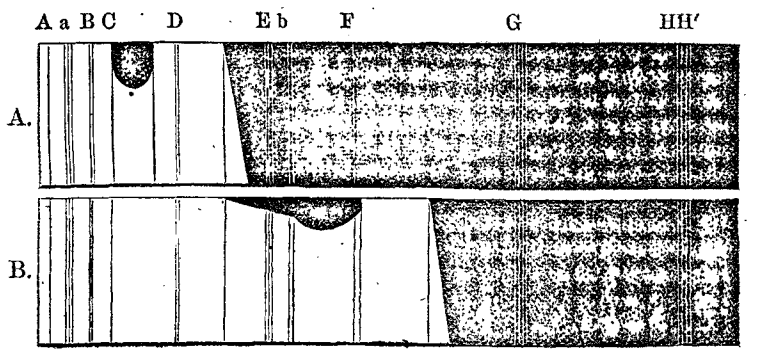
The extract of yelk of egg by chloroform or ether, after evaporation of the solvent, is a semifluid yellow mass, in which on standing fine crystals of lecithine are deposited. When it is shaken with concentrated acetic acid much luteine dissolves, and oily drops remain suspended. But none of the substances can at present be perfectly isolated. Treated with concentrated sulphuric acid it gives a blue reaction, due to luteine, which passes into green and then into red; this becomes darker every moment and shows spectrum:

Band in red and orange 40 to 53 = 13; intens. 3; R. α. In very dark solution the band reads 42 to 56. Yellow from 59 appears green and shaded to 71, where spectrum is cut off. The solution has a powerful green fluorescence.

On dilution blue appears at 114, reaching to 139, and in green a band remains, feeble from 74, becoming intensity 3 at 95, and ending at 114.

1. 40 to 53 = 13; Intens. 3; R. α.
2. 74 „ 114 = 40; „ 2; „ β.

When 2 can be seen and measured, 1 has quite disappeared. The first spectrum is therefore the primary (A.), and the last one the secondary (B.) spectrum.



Diagrams of Primary and Secondary Spectrum of Lecithine from Yelk of Eggs with Sulphuric Acid.

The spectrum A. has already been described and figured on p. 185 of the 10th Report of the Medical Officer, but is there erroneously named as that of vitelline. It is, however, correctly alluded to under its proper name in the comparison with the biliary tests on p. 256.

M.—*On Leucine, its Purification, Compounds with Copper, and Extraction from Morbid Fluids and Tissues.*

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1. *A new Mode of purifying Leucine.*

The study of the chemical and dynamical relations of this substance is of great importance, as it is not only a normal ingredient of some parts of the animal body, but a constant and copious product of the natural and artificial decomposition of albuminous substances. In pathological conditions of the human body it appears in various organs, particularly the liver, and then it is also not rarely excreted by the urine. (Malignant jaundice.) The circumstance that it is a homologue of glycocoll, (the normal copula of cholic acid in glycocholic acid of the bile, and of benzoic acid in the hippuric acid of the urine,) invests it with great theoretical interest. Some time ago I undertook an inquiry into some of its transformations, an account of which has been published in the Journal of the Chemical Society. The production of an acid free from nitrogen, and more oxydised than caproic acid, and of many of its salts, was the principal result of that inquiry. This leucic acid ($\mathrm{C_6H_{12}O_3}$) was shown to be homologous to lactic acid ($\mathrm{C_3H_6O_3}$), as the homology of leucine to glycocoll led the inquirer to suppose. But the great difficulty in procuring leucine in quantity prevented an extension of this research over a greater area. This has now been overcome to a great extent by the following new proceeding.

Process.

The raw leucine, as obtained by the inspissation and cooling of the mother liquors of tyroine, freed from mother liquor by pressure and dried, is treated with concentrated nitric acid while being triturated in a mortar and gently heated, until a slight reaction is perceived. The nitric acid solution is then diluted with water, and a solution of nitrate of oxyde of mercury is added as long as a precipitate is thereby produced. This is removed by filtration. The filtrate is allowed to stand for some days, during which time a reduction of mercury takes place. The excess of mercury is then removed by sulphuretted hydrogen. The filtrate is neutralized by ammonia and evaporated until a pellicle forms. The leucine which is separated on cooling is collected on a filter, washed with concentrated alcohol until the filtrate is colourless, and dried. It is then dissolved in boiling water, treated with pure animal charcoal, and filtered; the filtrate is evaporated in a covered china capsule (a Berlin porcelain capsule with wooden handle and spout and china cover is best for that purpose) until it is saturated on boiling, (forms a pellicle imme-

diately on the cover being removed,) and then poured into three or four times its volume of very strong alcohol. White leucine crystallises almost immediately, and on standing. After 24 hours the leucine is collected on the filter, washed with alcohol, and dried on blotting paper. If it is not perfectly white and brilliant and free from smell, it must be dissolved once more in boiling water filtered, and after concentration poured into alcohol.

Thus purified leucine is a matter of a very light specific gravity, owing to the excessive thinness of the scales; it is perfectly white and of great splendour; it can be sublimated in white flakes without leaving any residue; in short all possible chemical tests show it to be perfectly pure.

In this manner I have purified leucine obtained from horn; from human and other hair; from albumen; from fibrine; from the human liver in several diseases—paralysis and Bright's disease, pyæmia, and tetanus; from the human spleen and kidneys in pyæmia and tetanus; and from liver substance which was allowed to putrefy in a vessel from which air was excluded.

2. *On the Compounds of Leucine and Copper.*

Preliminary remarks.

a. Preliminary Remarks.—It is desirable to possess means by which leucine can be completely removed or precipitated from solutions in such a manner as not to interfere with their further analysis. When we consider the compounds of leucine hitherto known, it is clear that none of them offers the necessary conditions for the accomplishment of this object.

Leucine and cupric hydroxyde.

Leucine and cupric acetate.

The researches of Goessmann (Ann. Chem. 91, 133) had shown that copper oxyde readily combined with leucine, and formed a compound of slight solubility. But as for complete precipitation an excess of the oxyde would have to be used, it was to be apprehended that the copper compound obtained must contain an admixture of basic salt, or of uncombined oxyde, and could therefore not be analysed directly, but had to be re-formed into a compound of definite proportions. It had been stated by Strecker that leucine displaced the acid of copper acetate, and formed an insoluble compound with the metal. To the application of this reaction there was the objection that it imported acetic acid into fluids which may contain this or nearly allied acids as essential ingredients. I therefore endeavoured to find a process which should combine all leucine contained in any fluid at once with an invariable quantity of copper, without leaving any excess of copper or any other acid in the fluid, and should subsequently yield the leucine copper compound in an insoluble form ready for analysis. This was effected by the following proceeding.

Mode of obtaining new compound.

b. Mode of obtaining new Copper Compound of Leucine, or Dicupric Trileucine.—On adding to a solution of leucine cautiously a concentrated solution of copper sulphate, until caustic potash produces a precipitate in a filtered sample of the cold solution, a fluid of a deep blue colour is obtained. This is treated with barium carbonate and boiled until an excess of this earth does not any longer cause effervescence, and a filtered sample of the solution remains clear with barium chloride and nitric acid. The filtrate, a fluid of a beautiful deep blue colour, is free from sulphuric acid, contains a quantity of copper in solution which stands in a certain proportion to the amount of leucine present, and on evaporation on the water bath at a gentle heat on standing and cooling deposits a light blue mass of crystalline granules. The new compound after being washed with water for some time is then washed with alcohol until the washings are colourless, and dried over sulphuric acid. It is a pale blue granular mass and becomes sky-blue

Properties of new product.

by being powdered. It leaves copper oxyde on combustion. When heated in a glass tube open at both ends it emits white and alkaline fumes of the strong and characteristic odour of amylamine. When the compound is boiled with water little only dissolves. Its mother liquor evaporated to dryness, and again treated with water to the extent of the original solution, deposits a further mass of scales and crusts, which are also nearly insoluble in even boiling water. Thus almost the entire amount of leucine contained in the fluid is obtained in the form of this insoluble copper-compound.

Analyses.—Dried in the steam-closet until the weight was constant— Analyses.

a. 0·345 grm. gradually ignited gave 0·1044 grm. of copper oxyde, equal to 0·0833 of Cu, or 24·14 °/₀ of copper in the compound.

b. 0·2946 ignited gave 0·091 CuO, equal to 0·0726 Cu, or 24·64 °/₀.

c. 0·5248, burned with soda-lime, gave out ammonia, which combined with 0·3036 grm. of platinum, &c., and therefore contained 0·04357 grm. of nitrogen, or 8·30 °/₀.

Second Mode of obtaining.—The same compound was obtained by boiling a solution of leucine with bright copper wire newly reduced in hydrogen, for some days on the sand bath. The salt was deposited from the solution filtered boiling; the solution retained little copper, and contained excess of leucine. The compound was therefore soluble in a solution of leucine, but much less soluble in water. It was insoluble in strong acetic acid. The analysis gave the following result:— Second mode of obtaining.

d. 0·0785 grm. left 0·0240 CuO, equal to 24·42 °/₀ Cu.

Third Mode of obtaining.—The same compound was obtained by adding copper oxyde to a solution of leucine hydrochlorate. This experiment will be more fully described lower down. Third mode of obtaining.

e. 0·0912 grm. left 0·0270 grm. CuO, equal to 23·64 °/₀ Cu.

Fourth Mode of obtaining.—By evaporation of the mother liquor of monocupric dileucine obtained by copper acetate (see lower down). Fourth mode of obtaining.

f. 0·6339 left 0·1840 grm. CuO, equal to 23·17 °/₀ of Cu.

The compound obtained by the four processes described consists of three atoms of leucine, in which four atoms of hydrogen are substituted by two atoms of copper.

Its formula is $C_{18} H_{35} Cu_2 N_3 O_6$. Formula.

Atoms.	At. Weights.	in 100.	Found. a.	b.	c.	d.	Mean.
C_{18}	216	"	"	"	"	"	"
H_{35}	35	"	"	"	"	"	"
Cu_2	126·8	24·58	24·14	24·64		24·42	24·47
N^3	42	8·14	"	"	8·30		
O_6	96						
	515·8						

Synopsis of analyses.

This compound, therefore, stands midways between the neutral salt $C_{12} H_{24} Cu N_2 O_4$, requiring 19·6 °/₀ of Cu and a hypothetical cupric monoleucine $C_6 H_{11} Cu NO_2$, demanding in theory 32·95 °/₀ of Cu.

The mixture of leucine and copper sulphate assumes a deep blue colour immediately on the addition of the sulphate. The colour is darker than that of the saturated copper sulphate solution, even when only a few drops of it are added to a saturated leucine solution, which if Deep blue colour of leucine and copper sulphate mixture.

they were added to the same bulk of water would be scarcely sufficient to impart to it any blue tint whatever. The amido-acid in the sulphate therefore increases the colour of the copper salt analogous to ammonia. The removal of the sulphuric acid and excess of copper oxyde by barium carbonate leaves the solution still darker.

Spectral analysis of blue solution.

Both solutions examined in the spectroscope absorb one half of the red part of the spectrum. The yellow and orange become green, the green dark, the blue lighter, but no detached absorption bands are discernible with lamp-light. The salts therefore behave like inorganic copper-salts.

(*f.*) *Application of the Method to the Separation of Leucine from Extract of a Liver suspected to contain Leucine.*

Separation of leucine from liver.

The liver was extracted with boiling water, the extract treated with lead acetate, the filtrate freed from lead by hydrothion, and evaporated to crystallisation. The mother liquor was separated, the residue treated with spirit, the spirit extract dried, dissolved in water, and saturated with copper oxyde by the addition of cupric sulphate and boiling with barium carbonate. A deep blue solution resulted, in which on evaporation some reduction of copper took place. The insoluble greenish blue leucine-copper was separated and washed, dried at 110°, and analysed.

(*a.*) 1·4703 grm. burned in platinum crucible left 0·4284 grm. copper oxyde, or 23·26 °/₀ of Cu.

(*b.*) 0·7171 grm. burned in platinum crucible left 0·2077 CuO, or 23·12 °/₀ Cu.

(*c.*) 0·6614 grm. burned in china capsule gave 0·1899 CuO, or 22·92 °/₀ of Cu.

The mean of these analyses is 23·10 °/₀ of Cu, and differs from the mean found in the pure preparation by 1·2 °/₀, from theory by 1·4 °/₀. This difference is, however, unimportant, as the data still support the theory, and because the difference is fully accounted for by the slight deoxydation and consequent separation in the form of pulverulent suboxyde of copper which a minute portion of the dissolved copper oxyde experienced. In a similar case it would be necessary to allow the oxydisable matter to saturate itself with oxygen from copper, and then to saturate the leucine, which has been deprived of a portion of its copper, a second time with copper oxyde. This may be done in all cases where a very pure preparation is desired at once, and a considerable loss of leucine by the earlier precipitation of the compound is of secondary importance. It is best to employ copper oxyde which has been kept under water and become finely pulverulent and reddish black. In some cases a few drops of a solution of copper acetate may be sufficient to restore the deoxydised copper.

To impure extracts of organs which contain much undefined oxydisable matter the method is as yet not well applicable. The product obtained is green and very impure. Nevertheless, from some extracts of cholera organs which had been analysed for urea some scales of copper leucine could be extracted which admitted of perfect identification.

(*g.*) *Monocupric Dileucine, obtained by means of Copper Acetate.*

Leucine copper made by adding copper acetate to a hot solution of leucine.

On adding to a concentrated hot solution of leucine kept on the steam-bath a quantity of saturated solution of copper acetate, the fluid becomes for a moment deep blue, and then immediately deposits a light granular precipitate. This increases by stirring, and the fluid is decolorised. The continued addition of copper acetate brings the precipitate to a

maximum, and the fluid then remains of a more saturated blue. Thin scales form on the surface. They are decanted with the blue fluid from the precipitate, and the latter is placed on a filter. The washings are only faintly blue, lastly almost colourless. To boiling water the precipitate yields a portion of matter (monocupric trileucine and dicupric trileucine), which will be considered lower down. Dried at 110° until constant, it is a beautiful sky-blue powder with no particular lustre.

Analyses:—

(*a.*) 0·6353 grm. burned in a china crucible left 0·1490 grm. CuO, equal to 18·72 °/₀ Cu.

(*b.*) 0·6511 grm. left 0·1536 grm. CuO, equal to 18·85 °/₀ Cu.

(*c.*) 0·3492 grm. burned with lead chromate gave 0·5604 CO_2 and 0·2601 H_2O, equal to 43·77 °/₀ C and 8·27 °/₀ H.

From a comparison of the above analyses with the theory of anhydrous monocupric dileucine (atom. weight, 323·4),

Atoms.	Atomic weight.	In 100.	Found.			
			a.	b.	c.	Mean.
C_{12}	144	44·52	„	„	43·77	„
H_{24}	24	7·42	„	„	8·27	„
Cu	63·4	19·60	18·27	18·83	„	18·55

it will be seen that the carbon and hydrogen analyses support the theory of the anhydrous compound, containing in theory 2·4 °/₀ C more than the hydrated, better than that of the hydrated, stated below, while the copper meets the requirements of the hydrated salt. But as four different preparations hereafter to be described support the probability of this salt being always hydrated, the above salt may be assumed also to contain one atom of water.

The solution from which the foregoing compound had been deposited, on evaporation formed scales on its surface which resembled those of dicupric trileucine as obtained by the barium process. The fluid when allowed to cool became turbid. The washed precipitate after extraction with boiling water was analysed. 0·6339 grm. left 0·1840 grm. CuO, equal to 23·17 °/₀ Cu, or exactly the mean found in the compound from the liver extract (23·10 °/₀).

(*h.*) *Hydrated Monocupric Dileucine, obtained by saturating a boiling Solution of Leucine with Cupric Hydroxyde.*

Goessmann (Ann. Chem. 91, 133) obtained a compound of leucine and copper, by saturating a solution of the former, while boiling, with hydrated copper oxyde, and cautiously concentrating the solution on the water bath. On cooling a granular crystalline dark blue compound resembling oxyde of copper ammonia was deposited. When the solution was concentrated quickly the compound was deposited in scales on the surface and at the bottom of the fluid. The crystalline deposit and the scales were analysed together, and yielded the following numbers. The matter was dried at 100° C. The copper was found so low as to justify the assumption of the compound having been a hydrate. But the hydrogen was one per cent. below the theoretical quantity, and as will be seen from a comparison with the theory of the anhydrous salt, was actually 0·7 °/₀ below the theory of this latter. On the other hand, the carbon should have been rather higher, if the compound had been partially dehydrated. I once obtained a compound with a similar

amount of copper (18·62 °/₀), by treating a large quantity of leucine dissolved in weak spirit with some copper oxyde and metallic copper.

Theory of hydrated monocupric dileucine. Atomic weight = 341·4.

		In 100.	Goessmann.	Th.	Mean of compd. by Cu acetate.
C_{12}	144	42·17	41·33	,,	43·77
H_{26}	26	7·61	6·69	,,	8·27
Cu	63·4	18·56	18·20	18·62	18·55

(*i.*) *Dicupric Trileucine and Monocupric Dileucine obtained from Leucine Hydrochlorate by repeated addition of Copper Oxyde.*

The solution which remained after the mercury of some mercuric leucine had been precipitated by H_2S out of its HCl solution, was evaporated to dryness to chase away all excess of HCl, then redissolved, and while hot treated with cupric hydroxyde. An insoluble blue compound (No. 1) immediately formed. Analysis, 0·0912 grm. burned left 0·0270 grm. of copper oxyde, equal to 23·64 °/₀ Cu.

The solution was evaporated to dryness on the water bath, and yielded a blue compound (No. 2) covered by a thin layer of green. The latter, copper chloride, easily dissolved in water with a blue colour, while the blue compound remained undissolved. Dried at 110°. Analysis: 0·1986 grm. burned left 0·0452 CuO, equal to 18·17 °/₀ Cu.

The mother liquor or washings of the foregoing compound were heated and treated a second time with copper oxyde; this at first dissolved, but the clear solution began to get turbid and a new quantity of precipitate (No. 3) fell down.

Analysis: 0·1852 grm. left 0·0420 CuO, or 18·11 °/₀ Cu.

The filtrate from this was now saturated with copper oxyde, filtered from the excess, and the blue filtrate evaporated on the water bath. It deposited sky-blue granules (No. 4) besides green copper chloride. The latter was removed by washing with water.

Analysis: 0·2318 grm. left 0·0532 CuO, equal to 18·33 °/₀ Cu.

The filtrates were again evaporated, and deposited a salt (No. 5) which was analysed.

Analysis: 0·1067 grm. left 0·0248 grm. CuO, equal to 18·56 °/₀ Cu.

All the precipitates were washed until the washings were free from chlorine. The precipitates were then specially analysed for chlorine, but found not to contain any. The copper oxyde thus separated the leucine from the hydrochloric acid, forming at first and only once dicupric trileucine, afterwards under varying conditions four times monocupric dileucine. In each preparation copper chloride was found and observed to diminish until the last. It is therefore evident that leucine when evaporated with copper chloride in proper proportions drives out the hydrochloric acid almost as easily as the acetic acid from the acetates of copper and mercury.

Fluorescence of washings of the above solutions.

The latest washings from the above compounds were clear and colourless in transmitted light, even in thick layers. But they fluoresced copper blue in diffuse light, and strongly whitish blue in sunlight. Sunlight thrown into the fluid with a lens produced an intense white blue pencil of fluorescence.

Synopsis of the quantity °/₀ of Cu found in the compounds:—

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
23·64.	18·17.	18·11.	18·33.	18·56.

The last preparation thus contained exactly the amount of copper required by the hydrated monocupric dileucine.

(*k.*) *Monocupric Trileucine.*—$\mathfrak{C}_{18}\ H_{37}\ \mathfrak{C}u\ N_3\ \mathfrak{O}_6$.—When the first granular precipitate, which is produced by copper acetate in a hot solution of leucine, is after complete washing with cold water boiled in a large quantity of water, a small quantity of two compounds dissolves, of which the one is deposited from the filtrate on cooling in light crystalline clouds; the other remains in solution. Under the microscope the deposit appears as rosettes of scales, belonging to the rhombic system apparently. But the angles of the scales are very uncertain. Washed and dried they form an exceedingly light mass, of the peculiar lustre of leucine itself, having also its fatty feel, but in addition a splendid soft light sky-blue colour. The masses are so highly electric that they adhere to paper or a knife like needles to a magnet.

Analysis: 0·1515 grm. on combustion left 0·0273 $\mathfrak{C}u\mathfrak{O}$, equal to 14·38 °/₀ $\mathfrak{C}u$.

Theory of monocupric trileucine:—

		Calc. in 100.	Found.
$\mathfrak{C}_{18}$	216	"	"
H_{37}	37	"	"
$\mathfrak{C}u$	63·4	13·95	14·38
N_3	42		
$\mathfrak{O}_6$	96		
	454·4		

The mother liquor from which the foregoing compound had been deposited measured 358 C.C., had a faint blue colour, and on evaporation to dryness left a quantity of salt, which dried at 110° C. weighed 0·1012 grm. On combustion it left 0·0283 grm. $\mathfrak{C}u\mathfrak{O}$, equal to 22·29 °/₀ $\mathfrak{C}u$. and was therefore dicupric trileucine.

A precipitate was therefore formed by the copper acetate in the leucine solution, which consisted mainly of *monocupric dileucine.* From this boiling water extracted *monocupric trileucine*, which was deposited on cooling of the water, and *dicupric trileucine*, which was left pure after the evaporation of the fluid. It is possible that the latter two bodies were originally formed and mixed with the first compound. It may, however, also be supposed that monocupric dileucine is decomposable by boiling at a certain period after its formation, and in small quantity, and that three atoms of it break up according to the following formula:—

(L = leucine.)

$$\underbrace{\left\{\begin{matrix}L\,L\\ \mathfrak{C}u\end{matrix}\right\}\quad\left\{\begin{matrix}L\,L\\ \mathfrak{C}u\end{matrix}\right\}\quad\left\{\begin{matrix}L\,L\\ \mathfrak{C}u\end{matrix}\right\}}_{\substack{\text{3 atoms monocupric}\\ \text{dileucine.}\\ \mathfrak{C}u = 18\cdot56\,\%}} = \underset{\substack{\text{1 atom monocupric}\\ \text{trileucine.}\\ \mathfrak{C}u = 13\cdot95\,\%}}{\left\{\begin{matrix}L\,L\,L\\ \mathfrak{C}u\end{matrix}\right\}} + \underset{\substack{\text{1 atom dicupric}\\ \text{trileucine.}\\ \mathfrak{C}u = 24\cdot58\,\%}}{\left\{\begin{matrix}L\,L\,L\\ \mathfrak{C}u\mathfrak{C}u\end{matrix}\right\}}$$

3. *On a new Compound of Leucine and Mercury, Pentamercuric Hexaleucine.*

The neutral compound $\mathfrak{C}_{12}\ H_{24}\ \mathfrak{H}g\ N_2\ \mathfrak{O}_4$ is made by dissolving such a quantity of freshly precipitated mercury oxyde in a hot solution

of leucine, that on cooling a turbidity ensues in the fluid. This solution on evaporation deposits the above salt. But when it was attempted to obtain this compound by acetate, as in the analogous case of the copper-compound, a new salt was obtained.

To a hot solution of leucine a concentrated neutral solution of mercury acetate was given, and the mixture heated gently. A white granular precipitate ensued, which was separated by the filter from the hot fluid. (First precipitate.) The mother liquor was evaporated by steam to a concentrated state, when much acetic acid escaped, but no deposit ensued. The addition of water produced an immediate white, slightly pink precipitate. The acid compound was evidently decomposed by water. The precipitate was filtered off and washed. (Second precipitate.) The washing water made the filtrates again turbid.

First Precipitate, or Pentamercuric Hexaleucine.—The precipitate was washed, then suspended in hot water, boiled, filtered, and again washed. The filtrate contained a mercurial leucine compound. The precipitate was a slightly yellowish heavy powder. It was dried at 110° C.

Analysis : 4·2527 grm. were dissolved in dilute hydrochloric acid. A small quantity of yellowish impurity was removed by filtration, and the filter washed to exhaustion. The application of hydrothion yielded 2·8167 grm. of mercury sulphide, equal to 57·09 °/₀ Hg. This leads to $C_{36}\,H_{69}\,Hg_5\,N_6\,O_{12}$, as the formula of this compound, being *pentamercuric hexaleucine.*

$$\overbrace{\overbrace{Hg}^{L\,L}\quad Hg\quad Hg\quad Hg\quad Hg}$$
$$L\quad L\quad L\quad L\quad L$$

Atoms.	At. Wt. in 100.		Found.
36 C	432	,,	,,
69 H	69	,,	,,
5 Hg	1000	57·94	57·09
6 N	84		
12 O	192		
	1777		

The *second precipitate*, after treatment like the first, did not appear to differ in composition or properties.

4. *Leucine-lead*, $C_{12}\,H_{12}\,Pb\,N_2\,O_4$.—The neutral compound was obtained by Strecker by adding to a boiling mixture of leucine and lead acetate cautiously a little ammonia. When I took a solution of leucine, saturated boiling, added lead acetate and a little ammonia, only a trifling precipitate ensued while the fluid was boiling ; but on cooling, the whole fluid filled with this very insoluble compound of lead and leucine.

N.—*On a Series of New Yellow Substances contained in Animals and Plants.**

A. *Animal Series.*

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Introduction.

Introduction

The following researches arose in an endeavour to define chemically and spectrologically the substance which passes in works on morbid anatomy and chemistry under the name of "hematoidine." In this endeavour the author was completely disappointed, as during the examination of more than 1,200 different specimens of healthy or morbid tissues "hematoidine" was never once met with. The author does not, therefore, assume that hematoidine, as originally described by Virchow, does not exist. He believes, however, that several matters have erroneously been termed hematoidine, which were either cholophæine or luteine. Neither of these last two bodies have any apparent relation or similarity to hematoidine, or to any of the numerous derivates of the colouring matter of the blood which have been described in the Tenth Report of the Medical Officer. Luteine in particular offered properties so peculiar, that it was specially investigated, and there was found such a wide distribution of it, or of bodies very closely resembling it, that the subject was followed out as far as time and opportunity permitted. The whole of the new substances met with were, according to their spectra, and with regard to their origin and occurrence, divided into 10 classes. Of these only one class, namely, yellow substances with continued absorptions, have hitherto (as far as the author's acquaintance with literature reaches) been known to science; the spectra (and most of the bodies to which they belong)

* An abstract of these researches was communicated to the Royal Society by the Medical Officer, and was published on p. 253 et seq. of No. 108, vol. 17, of the Proceedings of that Society. An abstract also appeared in the Centralblatt für die Medizinischen Wissenschaften, January 1869.

of the other nine classes are here described for the first time. These researches show that specific absorption-phenomena are not, as has hitherto been believed, confined to the red, yellow, and green part of the spectrum, but occur, if not in the same variety, yet with the same or perhaps greater frequency in the blue, indigo, and violet part of the spectra, particularly of substances which present to the naked eye a yellow or orange colour.

The animal series of these substances claims particular consideration, on account of the important physiological and pathological questions which they concern: questions, for instance, as to the homologies of parts of the ovum, and as to the chemistry of the blood serum, and as to intestinal digestion, and as to the pathology of ovarian tumors, and generally as to cell-growth and secretion.

The spectroscopical observations were made with the methods and instruments which are described and figured by the author in previous reports, and which, for readiness and precision, he can strongly recommend to the attention of spectroscopical inquirers. To the author, at least, the spectroscope has become one of the most indispensable aids of inquiry in the laboratory. The diagnoses which it is capable of establishing between bodies of similar colours, or between bodies which by chemical reaction assume or yield similar colours, are striking and certain, and cannot be furnished so readily by any other mode of inquiry.

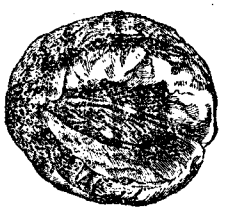
a.

On Ovario-luteine, the characteristic Yellow Ingredient of the Corpora Lutea of Mammals.

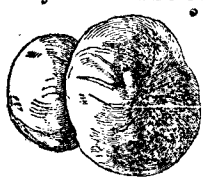
Corpora from ovaries.

The ovaries of cows and heifers were dissected, and corpora lutea from the size of a large filbert to that of a lentil removed. The large corpora had all what may be called a cap or a projection protruding over the round surface of the ovary. The larger they were the lighter was their colour. The large ones were yellow to orange, the small ones became red like cinnabar. Some came easily out of the tissue of the ovary, being attached only loosely by connective tissue; scraping rather than cutting was required to isolate them. Some contained a cavity filled with a clear yellow fluid. In one instance I removed this fluid with a pipette, and found it to measure about 3 cubic centimetres. A few minutes after its removal from the cavity it became firmly coagulated. The corpus was of equal thickness all round, the inner surface pale, white, and smooth, with many threads extended from wall to wall. There was no aperture in the corpus, which therefore represented a complete cyst. Other corpora came out of the ovaries with no less ease; but they were smaller and more solid to the touch, and contained a small cavity of the size of a pea, filled with yellowish coagulating fluid. The greater number of corpora, however, contained no cavity, but were quite solid, and in the place where a cavity might have been, and in my opinion was at an earlier stage of their growth, they showed stripes and streaks of white fibrous tissue. These corpora rarely had any protuberance. Smaller corpora were of darker colour, and adhered very firmly to the tissue of the ovary, drawing its sur-

Cavity of corpus filled with fibrinous fluid.

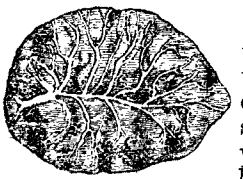


Solid corpora.



Small corpora.

face inwards after the fashion of an umbilicus. The smallest corpora were dark red, and frequently quite buried in the substance of the ovary. The corpora, particularly the large ones, were surrounded by many blood-vessels, but in none of them was there ever seen effused blood, or coagulated blood, even to the smallest extent, or any residue or appearance which could have led to the belief that there had been at one time an effusion into its cavity, or near to its periphery. No crystals of any kind, particularly no so-called hematoidine crystals, were ever met with. Microscopically the corpora lutea, while fresh and large, consisted of many large bodies, so-called cells, with a nucleus each, and a great quantity of feebly-coloured *granular matter* in the material surrounding the nucleus. This granular matter became darker as the cells grew older, and shrank, until at last in very dark-red corpora the granular bodies were dark, strongly defined, and impenetrable to light, as if all matter except the coloured ingredient had been extracted from the body or cell, and the outer membrane, if any such was there, had been contracted around the pigment.



No blood or crystals found.

Microscope shows nucleated bodies.

Dark old bodies.

A number of the corpora were pounded and put into a steam-oven in a dish. They drew a considerable amount of juice, which was turbid and reddish, and was poured off. It gave a precipitate with nitric acid, which pink at first became greenish yellow. It gave a precipitate, then a solution with sulphuric acid, which became reddish brown on standing. With sulphuric acid and sugar it became beautifully purple, like the fat from blood corpuscles or cod liver oil, or cerebric acid. Its spectrum showed a band in green:

Pulp of corpora draws a juice on heating.

Reactions of this juice.

Purple test.

76 to 113 = 37, int. 10, cut off at 155.

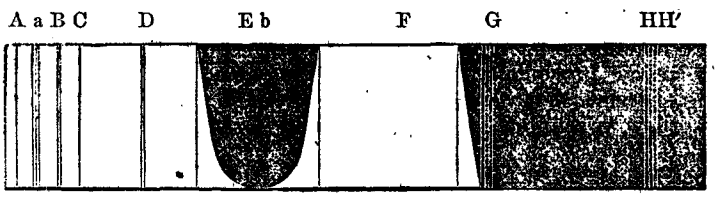


Diagram of Purple Test of Juice of Corpora.

More diluted with sulphuric acid the spectrum is: band 80 to 106 = 26, int. 4, cut off at 160. Blue splendid. Both observations made with Drummond's light. When this purple solution was poured into alcohol it either lost its colour when little in quantity, or when a larger amount was taken gave to the alcohol a smoky hue. The peculiar spectrum distinguishes this reaction from that of bile acids and cerebric acid. Hydrochloric acid gave no reaction in the watery juice, even on heating. The juice itself seemed colourless, as on filtration, which was very difficult, only a few drops of nearly colourless fluid passed. The colour of the turbid juice is therefore probably due to suspended particles, but the reaction seems to be due to both particles and fluid.

Diagnosis from bile acids.

The solid part of the corpora, when dry, was powdered and extracted with boiling alcohol of 85 per cent. by volume. A deep yellow solution was obtained, which was filtered on the steam-funnel, and immediately

Extraction of dry corpora lutea with alcohol.

Spectral analysis of alcohol extract. Measurements of spectrum.

became turbid. Subsequent extracts being added, the solution ultimately remained clear. The yellow solution before the spectroscope passed red, yellow, and green, until 85, where spectrum was decidedly cut off. Diluted with one-third of its volume of the same alcohol it exhibited two bands, one in blue and one in indigo.

Obs. (*a*.) (1.) 110 to 123 = 13 Int. 2.
(2.) 134 „ 152 = 18 „ 1.
Obs. (*b*.) (1.) 107 „ 120 = 13
(2.) 128 „ 149 = 21

Possible third feeble band in violet, at about 170. End at 195.

After repeated clarification of the solution, and with the aid of Drummond's light, the following final observation was made:—

Obs. (*c*.) (1.) 106 to 122
(2.) 130 „ 150
(3.) 165 „ 179
End at 198.

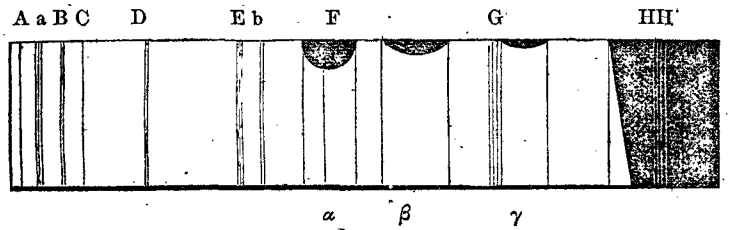


Diagram of Spectrum of Alcohol Extract of Corpora Lutea of Cow.

Turbidity by water.

The addition of a little water or of any watery reagent to the saturated alcohol solution caused a turbidity which did not dissolve on heating. The potash mixture alone became clear and formed a yellow deposit. Platinum tetrachloride, gold terchloride, and mercury perchloride produced no reaction, even on boiling. Neutral mercury nitrate caused a copious yellow precipitate, which on heating immediately, slower on standing, became snowy white. Mercury acetate produced a copious canary-yellow precipitate, which on boiling contracted, and left the fluid colourless.

Reactions with mercury nitrate and acetate.

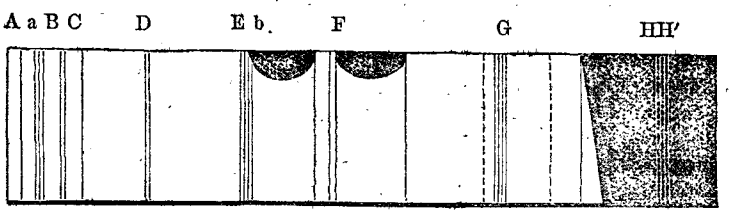
Reactions with acetates of copper, zinc, and lead.

Copper acetate produced a copious green precipitate, which became thicker on boiling, but the fluid remained turbid for days. The acetates of zinc and lead apparently produced no reaction at first, even on boiling, but on standing some days the mixture deposited all yellow matter as an oil at the bottom of the alcoholic solution. A solution of iodine in ammonium iodide produced no reaction.

Chloroform solution of luteine. Spectrum.

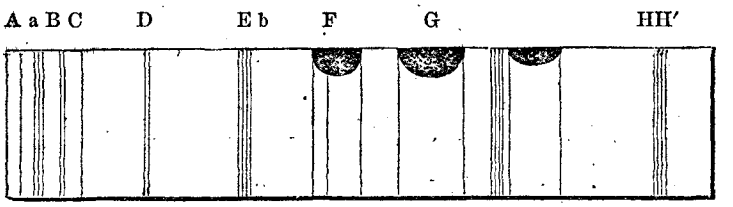
Chloroform extracted the yellow matter both from the fresh wet corpora and from the dry powder. The solution left the spectrum free to 85, when the blue was cut off. On continued dilution blue appeared, but there remained an absorption band, 93 to 110 = 17, int. 2, seen with gas-light. Drummond's light gave same measurement. On very cautious dilution a second absorption band, 119 to 136 = 17, int. 2, R. β, could be observed; spectrum cut off at 175. Other reading of medium concentrated solution:—

(1.) 90 to 100 = 20.
(2.) 116 „ 137 = 21.
Cut off at 189.



As compared to the spectrum of the alcoholic solution, the bands of the chloroform solution were moved from 12 to 16 points of the scale towards the red end, and the third band was not certainly visible.

The ether solution, on the other hand, of which spectrum is here subjoined, resembles the alcohol solution, its second and third bands being moved a little more towards the violet end.



Reactions of luteine with nitric and sulphuric acid

The chloroform solution evaporated before the bellows left a residue, which was white at first, ultimately yellow. This residue with a drop of nitric acid became blue for a moment, then colourless. The chloroform solution with nitric acid became colourless at once without any blue appearing. The very peculiar odour of luteine which appeared most strongly during the evaporation of the chloroform, reminded me much of the odour of cancer juice. The yellow residue did not dissolve easily in cold alcohol, but required heating. By concentrated sulphuric acid it was coloured of a dirty green, which at the margin in the thinnest layers appeared blue. When a little sugar was added to the solution no purple appeared, from which it became probable that the reaction of the juice above described belongs to a matter not being luteine.

Odour like cancer juice.

Crystals of luteine.

When the alcohol solution is left to spontaneous evaporation, a semi-fluid fat-like matter remains, in which on standing crystals are deposited, while the fat loses nearly all its colour. The crystals are orange red in transmitted light. They can but imperfectly be isolated from the semi-fluid fat in the following manner:—The mixture is repeatedly shaken with absolute alcohol, in which the fat dissolves to a great extent, while the crystals are almost insoluble in it. What remains after decantation of the alcohol is repeatedly shaken with small portions of ether. The rest of the fatty matter now dissolves, and the crystals remain free, although deadened in appearance and corroded by the ether, which dissolves a portion of their substance. The crystals are washed on a filter with a little ether, pressed between paper, and dried.

Reactions of the crystals.

The crystals are soluble in chloroform with a yellow, in a concentrated state fiery orange, colour; in absolute ether with a yellow colour, less easily than in chloroform; in sulphide of carbon with a fiery red colour, which by dilution becomes orange yellow. Glacial acetic acid dissolves the crystals on heating only. Dilute acetic acid, dilute mineral acids, ammonia, caustic soda, do not dissolve the crystals. Nitric acid poured over the crystals produces a blue colour, which immediately

passes into yellow. When dilute or concentrated nitric acid is added to the solution of the crystals in acetic acid, the blue colour is also produced, but disappears immediately. Neither the chloroform nor the ether or alcohol solution give any blue colour with nitric acid; the solutions are simply discoloured.

b.

Ovo-luteine, the characteristic Yellow Ingredient of the Yelks of Hens' Eggs.

Chloroform extract.

Yelks of hens' eggs were shaken with chloroform. On standing, a yellow solution settled, on which white vitelline floated. The solution, assumed to be saturated, had spectrum of three bands in blue, indigo, and violet.

1. 99 to 117 = 18 ; int. 2. R. α.
2. 125 „ 145 = 20 ; „ 2. „ β.
3. 155 „ 174 = 19 ; „ 1. „ γ.

End at 190.

Diluted with one-third volume of chloroform the solution showed spectrum—

1. 103 to 117 = 14 ; int. 2.
2. 126 „ 144 = 18 ; „ 2.
3. 159 „ 173 very feeble.

End at 196.

Again observed after standing 24 hours—

1. 103 to 117.
2. 126 „ 144.
3. 158 „ 172.

End at 200.

This solution shows the bands very well, and better than any of the following solutions in ether or alcohol. It is necessary to obtain the solution very brilliant by letting it stand, and filtering and decanting it repeatedly from deposits of aqueous matter.

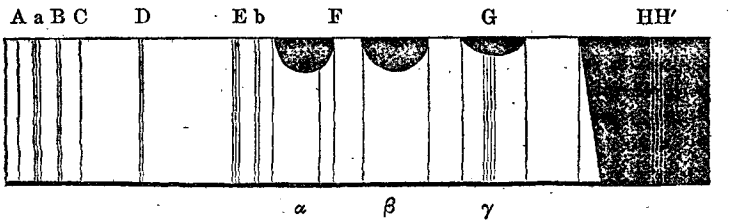


Diagram of Spectrum of Luteine from Yelk of Egg in Chloroform.

Ether extract.

The *ether solution* of the extract from yelk has a splendid yellow colour. In its saturated state one centimetre thickness cuts off the spectrum at 100 nearly. Much diluted there appears spectrum of bands—

1. 108 to 125 = 17; int. 2. R. α.
2. 134 „ 155 = 21; „ 2. „ β.
3. 168 „ 184 = 18; „ 1. „ γ.

End at 196.

More diluted the spectrum measured—

1. 110 to 125.
2. 135 „ 155.
3. 168 „ 184.

End at 205.

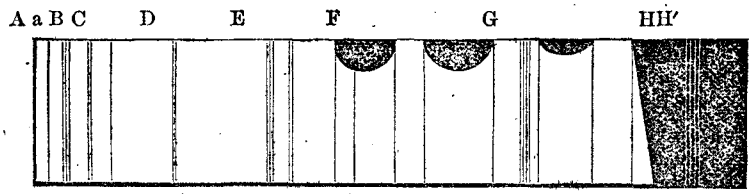


Diagram of Spectrum of Luteine from Yelk of Eggs in Ether.

Alcohol extract of yelks.

Yelk was boiled with alcohol of 85 per cent., and the filtrate separated on hot funnel. On cooling the solution immediately became turbid. In this turbid state it allowed the red and green of the spectrum to pass, although it was cloudy; complete darkness began at 112. On being heated it cleared up, and now allowed bands to be observed—

1. 111 to 128 = 17.
2. 135 „ 155 = 19.

It remained questionable whether or not there was a third band in violet, but traces of it were only perceptible while the fluid was very hot.

On standing the alcoholic solution deposited a fatty matter, and became quite clear. It showed three bands—

1. 108 to 124.
2. 134 „ 152.
3. 167 „ 183.

End at 200.

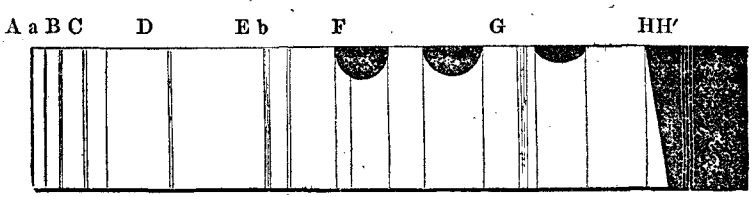


Diagram of Spectrum of Luteine from Yelk of Egg in Alcohol heated.

Bands lose intensity in hot fluid.

When this clear alcoholic solution was heated the intensity of the bands was diminished to less than one-half, the third band becoming quite imperceptible. On cooling the absorption bands gradually reassumed their former intensity.

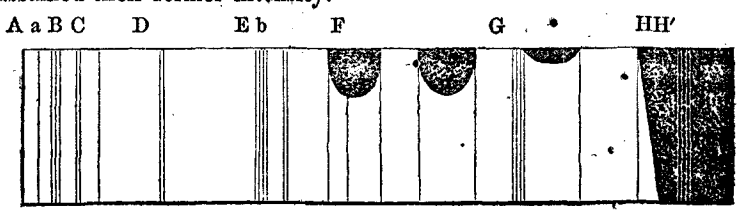


Diagram of Spectrum of Egg Luteine in Alcohol after cooling.

This phenomenon is the reverse of the one I observed upon vegetable matters, which became darker in their bands by heating. The red vapours of nitrous acid also show a greater absorption by heating, the absorption lines augmenting greatly in number with the rise of temperature.

Nitrous acid absorbs more while hot.

The bands of the heated luteine solution measured—

1. 110 to 126.
2. 137 „ 154.
3. 168 „ indistinct.

} Band appeared between gorgeous colours—bands of blue, indigo, and violet.

End at 196.

Comparison of spectra.

The spectrum of the alcoholic solution of luteine from yelk is therefore identical with that of the ether solution of the same substance. The spectrum of the chloroform solution differs, however, in this, that its three bands are displaced by about 10 points towards the red end of the spectrum, although they retain almost exactly their position relatively to each other. Similar displacements of bands produced by different solvents upon the spectra of the same bodies are not unfrequently observed.

Displacements of bands.

Comparison of Spectra of Luteine.

From Ovaries of Cows.	*From Hens' Eggs Yelks.*
Alcohol extract.	*Alcohol extract.*
1. 106 to 122 = 16 int. 2. R. α.	1. 108 to 124 = 16 int. 2. R. α.
2. 130 „ 150 = 20 „ 2. „ β.	2. 134 „ 152 = 18 „ 2. „ β.
3. 165 „ 179 = 14 „ 1. „ γ.	3. 167 „ 183 = 16 „ 1. „ γ.
End at 198.	End at 200.
Chloroform extract.	*Chloroform extract.*
1. 90 to 110 = 20 int. 2. R. α.	1. 103 to 117 = 14 int. 2. R. α.
2. 116 „ 137 = 21 „ 2. „ β.	2. 126 „ 144 = 18 „ 2. „ β.
3. Observed, but margins not defined.	3. 158 „ 172 = 14 „ 1. „ γ.
Cut off at 189.	End at 200.
Ether extract.	*Ether extract.*
1. 110 to 125=15; int. 2. R. α.	1. 108 to 125 = 17 int. 2. R. α.
2. 135 „ 155=20; „ 2; „ β.	2. 134 „ 155 = 21 „ 2. „ β.
3. 168 „ 184=18; „ 1; „ γ.	3. 168 „ 184 = 18 „ 1. „ γ.
	End at 196.

There is no doubt that if all spectra could be measured at one and the same time, and with one and the same intensity of light, the coincidence of the data would yet be greater than it is. Upon a comparison of all the data, and taking into consideration the chemical reactions above described, we are justified in assuming that:—1. The spectra of the various extracts from the corpora lutea are identical with those of the several extracts from hens' eggs. 2. A fortiori the body producing the spectra in the extracts from the corpora is chemically identical with that producing the spectra in the extracts from yelks. 3. This body is a yellow crystallizable substance which has not hitherto been defined, to which I attribute the name of luteine.

This body has, however, repeatedly engaged the attention of inquirers. Thus Holm, under the guidance of Städeler, isolated it, and described

(Erdmann's Journal, vol. 100, p. 142) most of its properties, excepting the spectroscopical ones, but believed it to be hematoidine. But *luteine* differs entirely from *hematoidine*. Luteine is the specific physiological product of a certain normal cell-formation which builds up the corpora lutea. Hematoidine is an abnormal product of pathological processes, or at all events an accidental formation derived from effused blood out of the circle of vital action. Luteine is deposited in granules within cells, a product of their chemical life; hematoidine is deposited in crystals and irregular masses in the midst of effused and decomposing blood. The idea that the yellow or red matter of the corpora lutea was hematoidine originated from the circumstance that corpora lutea sometimes, in a few animals such as sows, and sometimes in women who have died of disease, contain extravasated blood in their centre, and in this a few crystals of hematoidine. This blood is a pathological formation, or if not, at all events an abnormal one. For in the hundreds of ovaries from cows, sheep, or other animals which I have dissected, I have only twice found any effused blood in the corpora lutea, and only once in any other part of the ovaries than the arteries and veins. Bischoff (Entwicklungsgeschichte der Säugethiere, p. 32, et seq.) gives a description of the corpora lutea to which I assent in all its features. He says nothing of the bloodclot which has latterly been so often alluded to in relation to hematoidine, and which has actually been figured by Henle (Anatomie des Menschen, Vol. II. p. 478, fig. 372, ref. 5) as situated in the cavity or in the midst of the corpus luteum, already approaching its natural greatest size. However often such abnormal products may have been observed by others, the hematoidine crystals contained in the interior of these little ovarian apoplectic effusions are things which are quite different from the granular luteine contained in the cells of the corpora lutea, even of those corpora lutea which may contain such a sanguineous effusion, though they may be lying side by side. Still less probability has now the view originally propounded by Paterson (Edinb. Med. and Surg. J., Vol. 53, No. 142, 1840, p. 1, and No. 45, p. 390), that the corpus luteum was the product of the transformation of an effusion of blood between the two layers of the Graafian follicle. The corpus luteum is a new growth from the membrana granulosa of the follicle, in the formation of which extravasated blood has no share, and the development of which it could only impede. Städeler (Erdmann's Journ., Vol. 100, p. 148) investigated the nature of the yellow matter in the yelks of eggs, probably in connexion with the studies of Holm. He did not obtain a crystallized body, and came to the conclusion that the yellow matter was either hematoidine (such as Holm had defined it), or some very nearly related body. The spectral phenomena of the extracts from yelk did not engage his attention.

References to literature.

Diagnosis from hematoidine.

Luteine has no chemical or physical relation to hematoidine, or any other derivate of hematocrystalline. The latter when treated with sulphuric acid all yield cruentine, with a variety of modifications, and peculiar absorption spectra, several of which I described in the last Report. Luteine becomes blue, then green, with sulphuric acid, and then shows no spectrum at all like anything obtained from blood. Luteine has its absorption bands in blue, indigo, and violet, while all derivates of hematocrystalline have their absorption bands in red, yellow, and green, hematine alone just leading with its last band into blue. The hematine nucleus of hematocrystalline is very difficult to destroy by chemical agents, and even strong reagents produce changes so to say only upon its surface. Luteine is easily and permanently altered by the same agents. Nitric acid transforms all relations or derivates of hematocrystalline

with difficulty into intense yellow substances; but luteine is by nitric acid and some nitrates immediately transformed into a colourless or white product. The crystals of luteine have no similarity either in shape, size, or appearance, to those of hematoidine; their facile solubility in ether, chloroform, and alcohol, distinguishes them entirely from hematoidine, which is quite insoluble in these agents. When Valentiner (Günsburg's Zeitschrift N. F. 1, 46, 1859) stated that he had extracted "hematoidine" from gallstones by means of chloroform, he mistook cholophæine or bilirubine for hematoidine. Cholophæine differs as much from hematoidine on the one as from luteine on the other hand. The mistake of Valentiner was repeated more formally by Robin and Riche (Compt. Rend. de Séances de l'Acad. de Sc. Tome 41, Séance du 1ER Octob. 1855), who obtained a quantity of cholophæine from a cyst in the liver, and by the aid of three elementary analyses, which clearly show that they referred to cholophæine, came to the conclusion that they had to deal with hematosine (the body which we usually term hematine) which had lost its amorphous character, and its iron, taken up an atom of water, and become crystallized hematoidine. It is only necessary to compare the reaction of Robin and Riche's hematoidine crystals with the reaction of cholophæine which I have described, in order to be quite sure that they had cholophæine before them. On the other hand, none of the physical or chemical signs of their crystals are identical with those which Virchow has given as being characteristic of hematoidine.

Diagnosis of luteine from cholophæine.

What ultimately remains of hematoidine, when the various bodies which have been ranged under its name are eliminated, is not difficult to tell. Hematoidine is probably decomposed hematocrystalline. Its crystals are most likely pseudomorphoses of the original forms of hematocrystalline, consisting of the albuminous body intimately mixed with the hematine which before decomposition constituted the soluble and crystallizable hematocrystalline. The amorphous hematoidine on the other hand is so little defined, that we cannot at present receive it as a characterized chemical object.

I therefore add to the conclusions above given yet the following:—

4. Luteine differs entirely from hematoidine on the one and from cholophæine on the other hand, and must not, and after this exposition cannot, any longer be confounded with either of them. 5. The bodies described by Holm and Städeler under the name of hematoidine are not hematoidine but luteine. 6. The bodies described by Valentiner and by Robin, Riche, and Mercier under the name of hematoidine are not hematoidine but cholophæine or bilirubine. 7. Hematoidine is a useful expression for certain microscopical crystals and bodies occurring in effused blood, the substance of which has not as yet been chemically isolated or defined.

The discovery of luteine in the ovaries, and of its identity with the yellow matter of the yelks, may suggest some revision of the doctrine of the homologies between the various parts of the ova of mammals and the eggs of birds, and assist in elucidating the very obscure physiology of the corpora lutea. For, though it is easy to tell the mechanical purpose of these growths, it is difficult to explain the object of their peculiar chemical ingredients.

c.

Butyro-luteine, the yellow ingredient of Butter.

Yellow and white butter.

It had never to my knowledge been asked in scientific inquiries, to which particular circumstance butter owed its yellow colour. Butter,

particularly during winter, might assume a perfectly white colour, and then the prejudice of the producers or consumers termed it "poor." The vendors to avoid the effect of this error had recourse to artificial colouring ingredients. We shall see in the sequel how closely the dyeing agents used for this purpose, namely, the juice of carrots, and of the orleans berry or annatto, resemble, in their optical phenomena at all events, the natural butyro-luteine of good healthy butter.

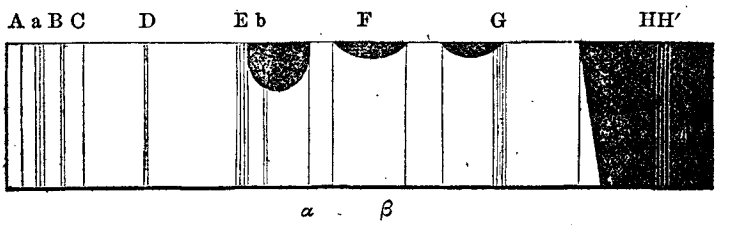
Dyed butter.

In August last I obtained a small quantity of the butter which is regularly supplied to St. Thomas's Hospital from a farm in the neighbourhood of London. It had a fine "rich" yellow colour, a pure fresh taste, and had been mixed with salt and formed into pats. On being fused in hot water it remained opaque, from the salt, water, and caseine; it was therefore mixed with an equal volume of chloroform, and the solution filtered from the deposit. This solution yielded spectrum—

St. Thomas's Hospital butter.

1. Band in blue, 90 to 108, Int. 2. R. α.
2. „ indigo, 116 „ 137, „ 1. „ β.
3. Third feeble band.

Ends at 189.



Intensity Diagram of Spectrum of Butter in Chloroform.

Another quantity of butter was now fused in a glass vessel, heated until all the water had boiled away, and the salt and caseine had been deposited, and filtered through paper on a heated funnel. In a test tube it showed a fine golden colour, and before the spectroscope it exhibited both the α and β bands of luteine, but moved by about 20 points more towards the violet end.

1. 110 to 123.
2. 134 to 153.
3. 159 to 173, very feeble.

End at 196.

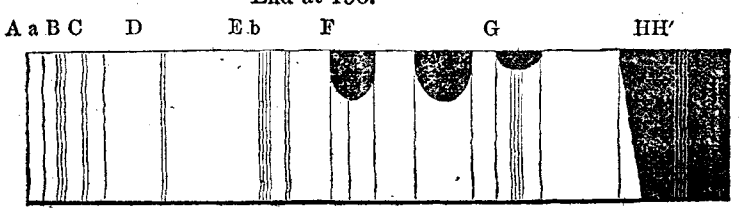


Diagram of Spectrum of Butter clarified and fused.

As the butter cooled the bands became more intense; the higher it was heated the less was the absorption exhibited by the bands. The third band was not visible while the butter was very hot, but became clearly visible a moment before it congealed.

d.

Cysto-luteine in the fluid contents of an Ovarian Cyst.

Luteine in fluid of an ovarian cyst.

The tumor came from a cow; the entire ovary was one large cyst measuring three inches in circumference and two inches in length. It

contained a yellow fluid, which amounted to 35 cubic centimetres by measure. A slight deposit of fibrine of the size of a pin's head was observed in it; it fluoresced green.

Spectrum: In thick layers red, yellow, and green, to 87, appeared, where the spectrum was suddenly cut off. Diluted with half water bands appeared—

1. In green 92 to 108=17; Int. 5; R. α.
2. In blue 115 „ 130=15; „ 3; „ β.

With gaslight it remained questionable whether or not there was a third band. Drummond's light with a layer of the natural solution 1 ctr. in thickness gave spectrum—

1. 92 to 108=17; Int. 5; R. α.
2. 116 „ 138=22; „ 5; „ β.
3. 150 „ 163=13; „ 1; „ γ.

End of violet at 195.

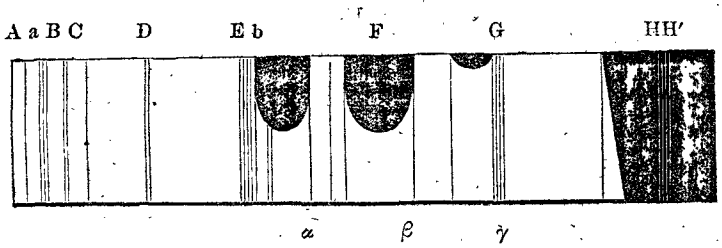


Diagram of Spectrum of Luteine from Ovarian Cyst.

The serous solution therefore yields the same measurements as the chloroform solution of ovario-luteine; it therefore probably contains the same kind of luteine as the corpora lutea. When I attempted to extract it the following was observed:—The fluid was so albuminous that on heating it became solid in the tube. Alcohol precipitated an immense quantity of albumen of a white colour, and itself assumed hardly any yellow colour. The luteine therefore adheres strongly to the precipitated albumen. I therefore preserved the mixture for a future favourable opportunity, when it may be treated together with larger quantities of similar matter.

Remarks.

The above observation, though single, appears to me particularly interesting; and it will be very important to ascertain whether the same holds good of ovarian cysts generally. The luteine contained insolubly in the cells of the corpora lutea is here dissolved in an albuminous liquid. If the deposition in granules was accompanied with the presence of fat in granules, the solution is distinguished by the absence of all fat. While together with fat luteine could be easily extracted by alcohol, it could scarcely be extracted by means of this agent from the albuminous solution. The cells of the corpus luteum had perished, or not been formed; the limitary membrane of the Graafian follicle had, however, apparently preserved a portion of its specificity as regards the chemical nature of its secretion. Fibrine, present in large quantity in the corpus luteum, was here only slightly represented; albumen prevailed, accompanied by the soluble alkaline phosphates, which also occur in abundance in the corpora lutea. The substance which I have above described as apparently attaching to the white corpuscles of the blood was not diagnosed in the serous fluid, and was probably absent.

Seroluteine from Animal Blood.

Seroluteine from animal blood.

It has long been supposed that the serum of the blood contained a yellow colouring matter, as it preserves a yellow colour, notwithstanding all measures which may be adopted for its clarification. It was surmised that this was colouring matter of bile, but this was negatived by direct research. Cholophæine occurs in the serum only in diseases, particularly obstructive diseases of the liver, or those which cause great congestion of the liver from a distance, like pneumonia and puerperal fever. Normal blood has never been found to contain cholophæine. In 1835 Martial Sanson published an essay on the colouring matters of the blood (Journ. de Pharm. 21, 420), in which he announced the existence of a yellow colouring matter by the side of the ordinary red ingredient, but he did not state that it was contained in the serum. He obtained it in the following matter :—Dried ox-blood was powdered and boiled in alcohol of 18°, whereby a little grease and some salts were removed. The powder was then washed with distilled water. The evaporation of these washing waters yielded a residue of deep yellow colour and strong salty taste. This residue was now dissolved in alcohol of 18°, afterwards in alcohol of 36° containing some ether; it was next filtered from albuminous and saline particles, and yielded ultimately a liquid which had a deep golden yellow colour.

Sanson's "matière jaune."

The blood thus deprived of its soluble salts and of a portion of its yellow matter, was dried, and repeatedly exhausted with boiling alcohol of 36°. The three first decoctions yielded on further treatment cholesterine and a small quantity of a brown matter, from which seroline could be separated. The fourth and subsequent decoctions were evaporated to dryness by themselves and left a mixture of three substances. From these cold water extracted a *yellow matter*, warm alcohol a fatty substance, and there remained a thin layer of bluish matter, which having been washed with alcohol and ether of temp. 40° C. dissolved in boiling alcohol with a fine *sky-blue colour*.

Properties of the "matière jaune."

Properties of the Yellow Matter.—It is soluble in water, alcohol, ether, and fats. The concentrated acids and alkalies do not change it while cold. When dry and in bulk its colour is orange yellow. By chlorine it is discoloured, but the liquid contains no iron. It is the colouring matter to which blood-serum owes its yellow colour, and it adheres to the fats which are extracted from blood by alcohol. As it easily combines with other matters it is very difficult to obtain it perfectly pure.

Properties of the "matière bleue."

Other proceeding for obtaining, and Properties of, the Blue Matter.—Blood is precipitated by basic lead acetate, the precipitate is dried, and boiled with alcohol of 36°. The liquid quickly assumes a blue colour. The first decoctions become turbid on cooling, and deposit a large quantity of fat, which carries the blue matter down with it; but after a time a tincture is obtained which remains transparent, and from which the blue matter can be isolated by the process stated above. When pure the blue matter is insoluble in cold alcohol, ether, and water; it is a little soluble in boiling alcohol, but is precipitated on cooling. The concentrated acids do not change it; the very concentrated sulphuric acid decomposes it. Ammonia by itself does not change it. Ammonia added to the alcoholic solution causes it to assume a greenish colour, and the subsequent addition of an acid restores the blue colour; chlorine discolours it; the fluid contains no iron.

Sanson states that Chevreul, Le Canu, and Lassaigne have met with

a similar blue matter in the blood of hysteric persons. He claims for himself the merit of having shown this matter to be a normal constituent of blood. F. Simon and other subsequent investigators could not find the blue matter again, and of the yellow they could not form a pure preparation or a clear idea. The production of a blue colour from blood by means of ozonised ether has invested this question with a new interest. To this we may add the question after the origin of the yellow matter in cholera urine, which with nitric acid yields a red and blue product, choleraic urorubine, and choleraic urocyanine, and the entire question of yellow, blue, and red matters observed in urine by a number of chemists. Seeing that luteine from eggs and ovaries also yields a blue colour by nitric acid, surmises are naturally aroused and tested experimentally.

Treatment of serum for luteine.

I caused a quantity of sheep's blood to be collected in a glass vessel in the slaughter-house, and to be placed in a secure corner. After 24 hours standing I carefully decanted the serum; this was now allowed to stand twice 24 hours in high cylindrical glass vessels, and the supernatant clear serum was drawn off from the deposit of blood corpuscles by means of a syphon. It was then filtered repeatedly through many folds of finest filtering paper, but by no means it could be made bright or translucent, it always retained a certain degree of opacity like ground glass. It was yellow, somewhat reminding of red. In layers of from $\frac{5}{8}$ to $\frac{3}{4}$ inch it showed the blood spectrum before the spectroscope, and with the most powerful Drummond's light which I could produce it exhibited the band α of luteine.

105 to 117=12 ; Int. 2 ; R. α. Blue interval to 125.

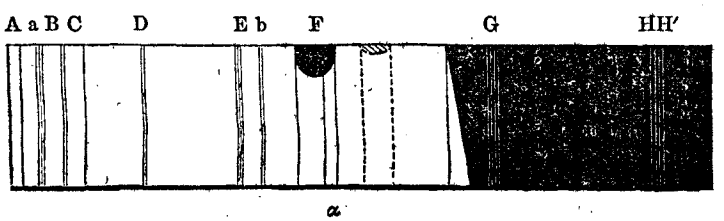


Diagram of Seroluteine. (*Blood-bands omitted.*)

(See also Plate V., fig. 10.)

I suspected at times the existence of a second band, at others all seemed to fuse into continued darkness. If the serum is diluted so that the absorption due to hematocrystalline is removed sufficiently so as not to interfere, the luteine bands become imperceptible. I have faintly indicated a second band on the plate, but I am not absolutely certain about it. I believe, from repeated experiments, that serum cannot by any means be perfectly freed from blood corpuscles. I have never seen serum without the blood-bands in the spectroscope, and it is not impossible that a great part of its yellow colour is due to these corpuscles. Although the above spectrum has been indubitably seen and scrutinized by me during an entire afternoon, I have failed in other specimens of serum to find it, and therefore it is possible that it may be an accidental ingredient. I have not yet succeeded in extracting it from serum, and believe that even if luteine were proved to be certainly and always present, the extraction would be exceedingly difficult. For I did not succeed, by a simple process of extraction

with alcohol, in obtaining any luteine from serum of an ovarian cyst, in which this substance was unquestionably present in large quantity; so strongly does it adhere to precipitated albumen.

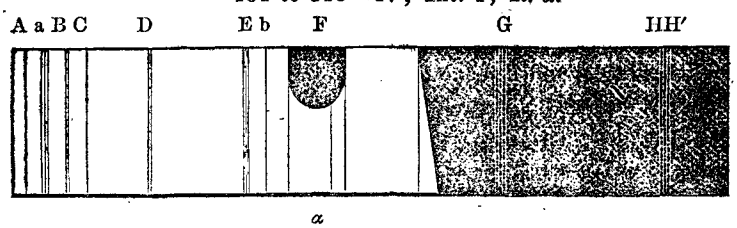
f.

Intestino-luteine from the Yellow Evacuations of sucking Infants.

Intestino-luteine from evacuations of sucking infants.

These fæces when healthy are of a golden yellow colour, semifluid consistency, and a slight odour of warm sour milk. It is difficult to obtain them without admixture, but their constituents cannot be mistaken. Mixed with alcohol in excess a great amount of a body having most of the properties of caseine falls down in flakes, while other matters dissolve, amongst them nearly the whole of the yellow coloured ingredient. The dilute solution exhibits an absorption band in blue, 103 to 115, which when the layer of fluid is made thicker gains in width, and becomes

101 to 118=17; Int. 4; R. *a*.



Intensity Diagram of Intestino-luteine.

Last reading 102 to 118. Only one band could be seen distinctly; a second band was suspected at 126 to 142, but from 130 every part to violet was already very dark. Chloroform and ether solution must be examined with a view to determine the question whether or not there is more than one band.

The alcoholic solution on standing became a little more red, but in thin layers was still yellow. It deposited a quantity of white cholesterine in crystals. After standing in a stoppered bottle for a period of six weeks it still showed the same spectral phenomena as at first.

Comparison of adult human excretions.

I compared some chloroform extract of dried adult human fæces which had been kept during several years, and had been repeatedly filtered from a precipitate which formed at intervals. The extract was yellow, showed no absorption band anywhere, and passed light to 167.

Physiological considerations.

Physiological considerations.—It has hitherto been generally accepted as a matter requiring no proof that the fæces of infants and adults owed their colour to an admixture of colouring matter of bile. Of course in the case of an omnivorous adult the accidental ingredients were also taken into account, but in infants the colour was to be derived from pure cholophæine. The above observation shows this surmise to be quite unfounded. Cholophæinates which are soluble in alcohol possess no absorption bands; the yellow extract of the evacuation of infants does not yield the reaction of cholophæine or bilirubine, and consequently, in the case of infants at the breast, cholophæine is not excreted. But another circumstance aided this erroneous belief, and this leads us to some pathological considerations. When infants fed upon milk become disarranged, their evacuations soon become green, and this phenomenon

Pathological considerations.

in itself is a sign of digestive disturbance. Now it was assumed that this green colour was due to biliverdine which had been produced from the bilirubine by the diseased process. It is, however, now very doubtful whether the green colour of diarrhœic fæces of infants, and of the meconium of the fœtus, is really produced by biliverdine. It is more probably a mixture of intestino-luteine with a peculiar blue product of its oxydation, or a green simple product of that oxydation.

Origin of intestino-luteine.

The origin of intestino-luteine itself it is not difficult to surmise. It might be derived from the milk, which, as I have shown above, contains in its butter globules a quantity of luteine with three bands. This luteine would therefore be required to undergo a considerable change before it could become intestino-luteine. But we have a much nearer source for this substance, and that is the mucous membrane of the intestine itself. The intestinal juice has a wine-yellow colour, as has been shown by the experiments of Thiry, lately confirmed by Quincke. It is probable that this colour is caused by the luteine here alluded to. The green colour of diarrhœic fæces might therefore be caused by a change in the secretive power of the membrane, or by an influence of the contents of the intestine upon the luteine secreted as such. Physiological inquirers, who have leisure to repeat the experiments of Thiry, should therefore be careful to place the intestinal juice before the spectroscope, in order to decide whether or not it possesses the absorption band of lacto-luteine above described.

B. *Vegetable Series.*

a.

Yellow Substances showing Spectra with continued Absorption of Blue, Indigo, and Violet, without detached Bands.

Such are exhibited by the yellow immediate principles of the following vegetable matters :—

French berries. (Chrysorhamnine, Xanthorhamnine.)
Weld or dyer's weed. (Luteoline.)
Quercitron. (Quercitrine.)
Turmeric. (Curcumine.)
Purrée. (Euxanthic acid.)
Careopsis lanceolata.
Heliochrysum bracteatum.
Viola lutea.
Acacia decurrens.
Helianthus macrophylla.
Berberis Darwinii.
Gnaphalium fœtidum.

French berries.

French Berries.—These berries are the fruit of several species of rhamnus. They differ in size and construction, but on an average are of the size of peas, and wrinkled all over their green surface ; they contain a number of small hard seeds, and have a disagreeable bitter taste. Of the four varieties of these berries which occur in trade I had only one, the real "graines d'Avignon," at my disposal ; the Persian, the Levantine or Turkish, and the Spanish berries are not easily obtained. The French berries come from rhamnus infectorius. The yellow matter obtained from a large light coloured variety of berries by Kane, chrysorhamnine, had the composition $C_{23}H_{22}O_{11}$. It was of golden yellow colour, insoluble in water, soluble in ether. By pro-

Chrysorhamnine and Xanthorhamnine.

longed boiling with water while exposed to air it absorbed 1 H_2O and 2O, and was transformed into xanthorhamnine $C_{23}H_{24}O_{14}$. This latter is soluble in water, but insoluble in ether; it is present, ready formed, in the dark brown variety of berries.

The watery or alcoholic solution of xanthorhamnine presents a continuous absorption of the blue end of the spectrum, without any detached bands. A saturated watery decoction of bruised berries was cleared up by alcohol. It passed all colours from red up to 107. Diluted +1 the absorption receded to 121; diluted +2 to 130; and 3 to 147; diluted to very pale yellow to 170.

Weld or Dyer's Weed (*Reseda luteola*).—Weld is now nearly obsolete as a dye, picric acid having taken its place. The entire plant is pervaded by a yellow colouring matter, which is extracted by decoction. This substance by its discoverer, Chevreul, has received the name of "luteoline." It crystallises in yellow needles, which sublime unchanged, are less soluble in water than in alcohol and ether, and have an acid character and reaction. Weld or dyer's weed. Luteoline.

In a decoction of weld greenish yellow flakes are deposited, consisting of luteoline and other matters in chemical combination. The filtrate is reddish yellow, and shows the general absorption of all yellow substances, namely obscuration of the violet, indigo, and blue parts of the spectrum to 138. Diluted it passes all colours to 160. By no treatment could I obtain separate bands; but as the solution seems to contain a red colouring matter as well as luteoline, the experiment should be repeated upon pure luteoline.

Quercitron.—This is the bark of an oak tree of North America, quercus nigra or tinctoria. A preparation sold at the drysalters is termed extract of quercitron or "flavine." I have not been able to ascertain the manner in which this is produced. Possibly it is an impure preparation of the substance called by Chevreul "quercitrine," namely, the deposit which forms when a decoction of the powdered bark is allowed to stand for some days. Bolley believed that this consisted of quercitric acid, $C_{16}H_{16}O_9$, H_2O. But Hlasiwetz (Ann. Chem. 112, 107) showed its formula to be $C_{29}H_{30}O_{17}$. I produced a boiling watery solution of the flavine, which was reddish and turbid. Its spectrum was cut off at 130 by a solution of the same tint as one of luteoline which cut off the spectrum at 135. The visible blue had a violet tinge. On dilution the absorption receded to 135; diluted +2 to 140; +3 to 145; +4 to 169. At this point it was only pale yellow. When still more diluted to quite pale yellow the entire spectrum to 188 passed. No bands were detached at any time. Quercitron. Flavine. Quercitrine.

Turmeric.—This substance, the root of yellow ginger, Curcuma longa, contains a yellow dye, curcumine, easily soluble in alcohol. A translucent solution passed red, &c., to 112; diluted blue to 117; more diluted to 125. Again diluted with alcohol a hazy violet appears to 146; more diluted indigo and violet to 185. No bands were detached at any time. But as the extract contains a fluorescent substance which exhibits a green colour in the cone of sunlight, (it is not proved that curcumine itself is that fluorescent substance,) the absorption of the blue and violet may be partly due to this matter, and not to the yellow dye only, which might possess bands; but the bands might disappear before the fluorescent body is sufficiently diluted to let any light at all pass in blue and violet. Turmeric becomes brown by alkali, and is used as a test for alkalis in chemistry. Turmeric, curcumine.

Fustet, or *fiset-wood*, the wood of Rhus cotinus, does not seem to be used in dyeing any more; I could not obtain any at the drysalters. Fustet obsolete.

Purrée or Indian yellow is a pigment of uncertain origin, probably the juice of a plant which is evaporated with magnesia. It contain *euxanthic acid* $C_{21} H_{18} O_{11}$. The solution of this acid is feebly coloured, and has no particular bands. Its dyeing qualities appear best in combination with bases, particularly magnesia. The pigment which I obtained in the colour shops had been treated in this country, and was in thin cakes, not the roundish lumps of commerce.

Purrée or Indian yellow.

The alcoholic extracts of the following *yellow flowers* also yielded spectra with continuous absorption of the blue end, without any bands.

Careopsis lanceolata.

Careopsis lanceolata.—Solution reddish-yellow, saturated. Cut off at 72; gradually to 100, where dark; diluted one-half recedes to 128; diluted two-thirds to 140. Diluted to pale yellow the entire spectrum passes. No bands at any time.

Heliochrysum bracteatum.

Heliochrysum bracteatum.—Orange yellow solution. Cut off gradually at 102. Diluted + 1 recedes to 124; + 2 recedes to 135; + 4 to 162; + 8 to 195. No bands at any time.

Viola lutea.

Viola lutea.—Light greenish yellow solution. Cut off at 129. Diluted + 1 recedes to 145; + 2 to 165; + 3 no further recession takes place, and no band is developed. The solution is now only palest greenish yellow.

Acacia decurrens.

Acacia decurrens.—Light greenish yellow solution. Cut off at 134. Diluted + 1 recedes to 148; + 2 to 155; + 5 to 163. The solution is now only palest yellow, + 10 to 170. Hardly coloured now; the matter which cuts off is perhaps colourless.

Helianthus macrophylla.

Helianthus macrophylla.—Solution pale yellow. Passes entire spectrum to 177, even in feeble light. No bands. Observation not conclusive; more concentrated solution to be examined.

Berberis Darwinii.

Berberis Darwinii.—Passes entire spectrum to 189. Questionable whether bands; more concentrated solution required, for which there was not enough material.

Gnaphalium fœtidum.

Gnaphalium fœtidum.—Cut off at 144. Diluted + 1 recedes to 160; + 2 to 165. No bands detached. Rest of spectrum very brilliant.

b.

Yellow Substances showing Spectra with a single Absorption Band.

Yellow wood.

Yellow wood, or *fustic,* is the wood of a kind of mulberry tree, *morus tinctoria.* It contains *moritannic acid,* $C_{18} H_{16} O_{10}$, which is the carrier of the tinctorial power, either free or in combination with calcium. To test its spectrum I made a decoction of powdered yellow wood, and evaporated the watery solution after filtration on the steam bath. After 24 hours standing an orange coloured precipitate, a mixture of the acid and its calcium salt, had deposited. Both the mother liquor and the solution of the isolated deposit presented the same spectral phenomena. The concentrated solution cut off the blue and violet and a portion of the green part of the spectrum.

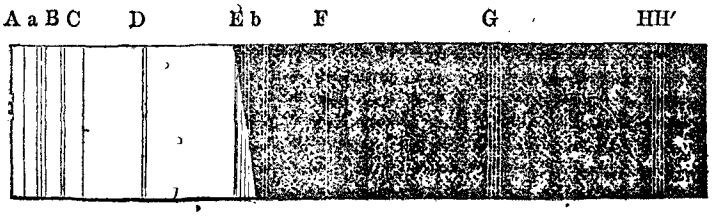


Diagram of Spectrum of Yellow Substances in general.

This absorption, common to all yellow coloured substances, I have also represented in fig. 1, plate I. But on dilution the absorption receded to 130, leaving a detached very pale band.

100 to 115=15; Int. 2; R. α.

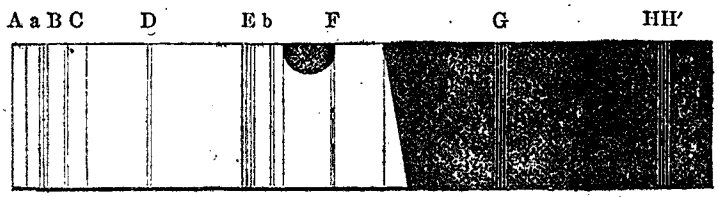


Diagram of Spectrum of Moritannic Acid.

See also Plate I., fig. 2.

I was not able to determine with certainty whether there was not a second band, as the solutions were always somewhat turbid, and the limits of this research did not permit me to follow the subject further. As, however, there are two analogous bodies, the one lactoluteine, already described, and the other the yellow colouring matter of the flower of the calceolaria, which possess but one absorption band in blue, and on further dilution do not exhibit any other detached absorption, I take confidence from these analogies to believe that moritannic acid also possesses but one absorption band.

Calceolaria.—The yellow variety of this esteemed flower yielded a cold alcoholic extract of a splendid *orange* colour, which exhibited a single absorption band in blue. Calceolaria.

1. 103 to 118=15; Int. 3; R. α.

Sharply cut off at 125.

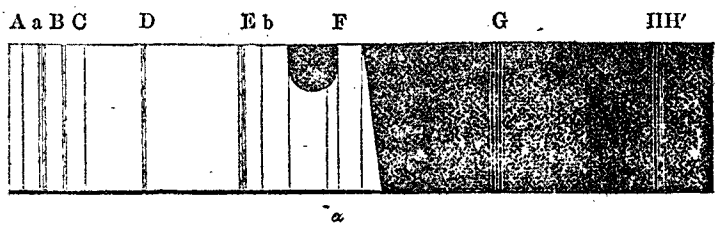


Diagram of Luteine of Calceolaria.

See also Plate I., fig. 3.

On further dilution violet to 145 appeared, the band α disappeared, and no new detached band was visible anywhere.

f.

Two-banded Luteine Spectra.

Yellow Vegetable Matters which show Spectra very much resembling that of Animal Luteine, but having probably Two Bands only.

1. *Crocus or saffron,* the stigmata and parts of the styles of a liliaceous plant, contains crocine, $C_{58} H_{81} O_{30}$ (?) It occurs also in the fruit of Gardenia grandiflora. Concentrated sulphuric acid transforms Crocus or saffron.

crocine into an indigo blue, later into a violet substance. Boiled with dilute acids it is split up into crocetine and sugar.

$$\underbrace{C_{58}\,H_{84}\,O_{30}}_{\text{Crocine.}} + 5\,H_2\,O = \underbrace{C_{34}\,H_{46}\,O_{11}}_{\text{Crocetine.}} + 4\,\underbrace{C_6\,H_{12}\,O_6}_{\text{Sugar.}}$$

Crocetine retains the principal dyeing properties of crocine, and its reaction with concentrated sulphuric acid.

A hot or cold alcoholic solution shows two bands in blue and indigo.

1. 114 to 135=21. Int. 4. R. α.
2. 145 „ 165=20. „ 4. „ β.

End at 184.

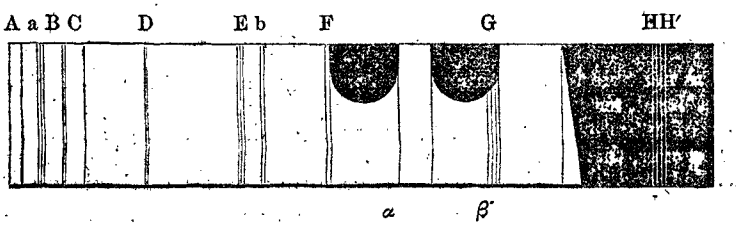


Diagram of Spectrum of Crocine.

See also Plate I., fig. 5.

In this spectrum the band β is placed more towards the violet end than in any other yellow solution I have yet examined. It just overlies the group of lines termed G; only in Verbascum phlomoides, plate III., fig. 2, does the second band just touch G.

Helianthus annuus, Sunflower.

2. *Helianthus annuus*, Sunflower.—A small flower of this kind, from St. Thomas's Hospital gardens, gave a yellow but turbid water extract. The alcohol extract, however, was clear, and of a splendid yellow colour. It showed spectrum—

1, in blue, 109 to 125=16. Int. 5 R. α.
2, in indigo, 136 to 157=21. „ 4 „ β.

Cut off at 172.

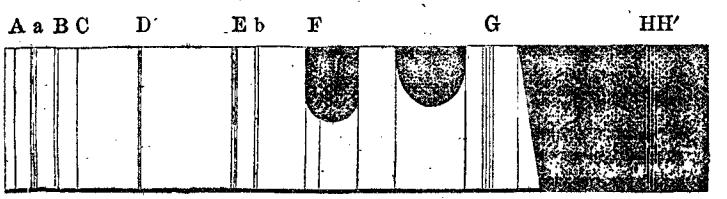


Diagram of Spectrum of Helianthus, yellow.

See also Plate I., fig. 6.

Much dilated, and with bright oxyhydrogen light, violet extends to 200, and there is probably no third band present.

Leontodon taraxacum, Dandelion.

3. *Leontodon taraxacum*, Dandelion.—The whole plant is officinal; in the Pharm. Brit. the root only. Alcohol extract of the flower, concentrated, is cut off at 105. Diluted bands appear.

1. 110 to 124=14. Int. 3.
2. 130 to 153=23. „ 4.

Suspected band begins about 166, if present. Remarkable that the second band is of greater intensity than the first.

More diluted, and with strongest Drummond light, the third band seems possible from 160 to 179. End at 205.

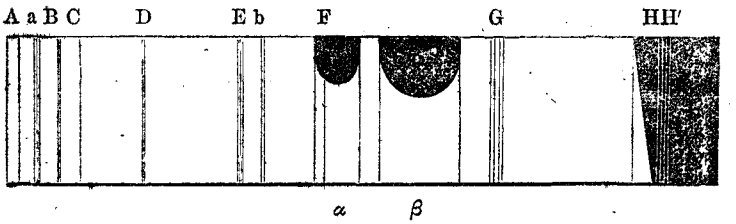


Diagram of Spectrum of Taraxacum—yellow.

See also Plate I., fig. 7.

4. *Hieracium pilosella,* yellow composite, from St. Thomas's Hospital gardens. Cold alcohol extract. Hieracium pilosella.

1. 110 to 125=15. Int. 3. R. α.
2. 135 „ 155=20. „ 3. „ β.

End at 190.

No third band appears on further dilution.

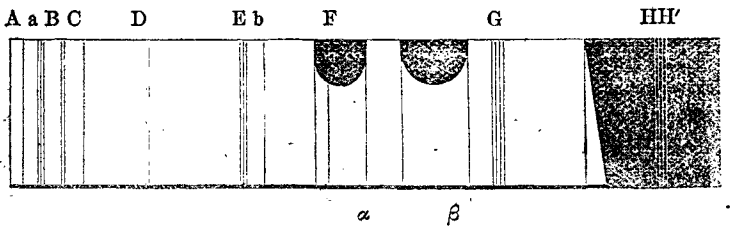


Diagram of Spectrum of Hieracium—yellow.

See also Plate I., fig. 8.

5. *Gazonia elegans.*—Flower orange, with black and white spots inside of petals. Has a white juice like Leontodon. Splendid deep yellow cold alcohol extract, not so orange as that of calceolaria. Gazonia elegans.

1. 105 to 128=23. Int. 4. R. α.
2. 137 „ 158=21. „ 4. „ β.

End at 169.

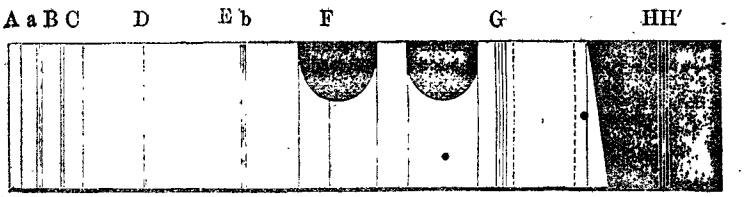


Diagram of Spectrum of Gazonia.

See also Plate I., fig. 9.

More diluted, violet is prolonged to 195, but a third band cannot certainly be distinguished. Stronger light and more solution allows a problematical shade 168 to 187 to be distinguished.

Hypericum oblongifolium.

6. *Hypericum oblongifolium.*—Solution yellow, made a deposit from which it was filtered.

1. 113 to 125=12. Int. 4. R. α.
2. 136 „ 152=16. „ 3. „ β.

Last term a little uncertain. End at 160; after dilution at 184.

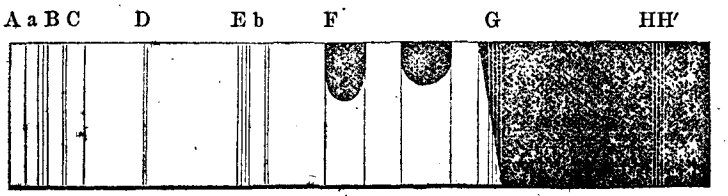


Diagram of Spectrum of Hypericum—yellow.

See also Plate I., fig. 10.

Acacia leprosa.

7. *Acacia leprosa.*

1. 113 to 127=14. Int. 4. R. α.
2. 136 „ 149=13. „ 3. „ β.

Last term uncertain. End at 170.

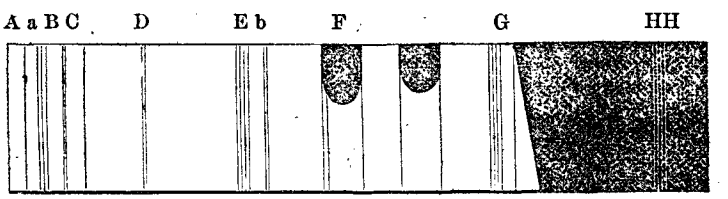


Diagram of Spectrum of Acacia leprosa.

See also Plate II., fig. 1.

Galphinia splendens.

8. *Galphinia splendens.*

1. 113 to 127=14. Int. 5. R. α.
2. 136 „ 155=19. „ 4. „ β.

Questionable third band. End at 191.

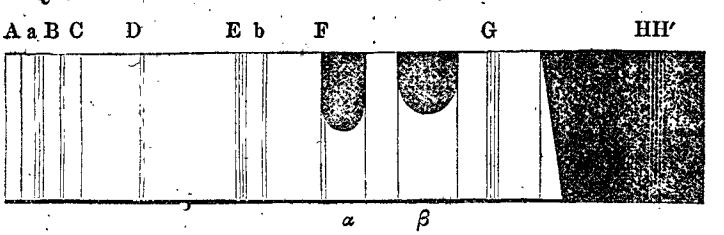


Diagram of Spectrum of Galphinia.

See also Plate II., fig. 2.

Stigmatophyllum ciliatum.

9. *Stigmatophyllum ciliatum.*

1. 115 to 129=14. Int. 4. R. α.
2. 137 „ 159=22. „ 3. „ β.

Questionable third band. End at 191.

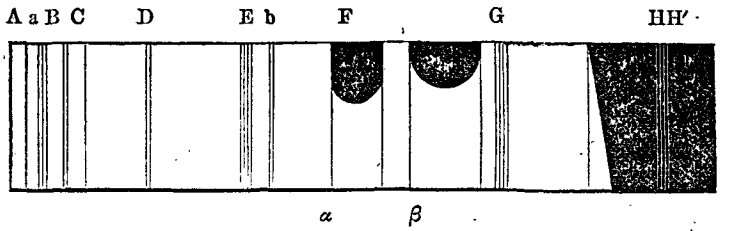


Diagram of Spectrum of Stigmatophyllum.

See also Plate II., fig. 3.

10. *Lankasteria elegans.*—Small quantity of dilute solution for examination. Lankasteria elegans.

1. 112 to 125.
2. 136 „ 155. Readings uncertain.

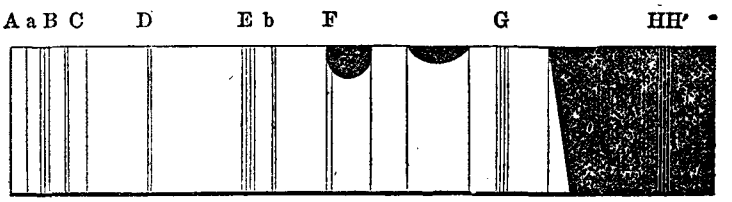


Diagram of Spectrum of Lankasteria flower.

See also Plate II., fig. 4.

11. *Allamanda Neriifolia.*—Splendid yellow flowers. Solution deep yellow. Allamanda Neriifolia.

1. 112 to 125=13. Int. 5. R. α.
2. 137 „ 157=20. „ 4. „ β.

End at 178.

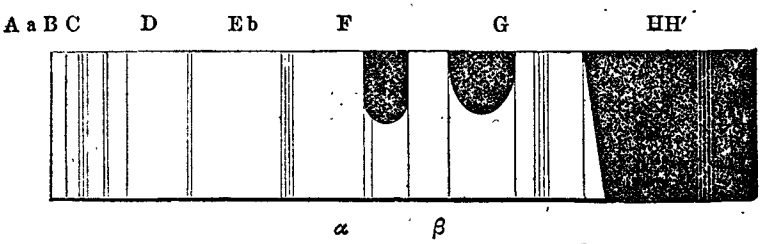


Diagram of Spectrum of Flower of Allamanda.

See also Plate II., fig. 5.

12. *Colutea frutescens.*—Solution slightly fluorescent. Colutea frutescens.

1. 107 to 119=12. Int. 3. R. α.
2. 128 „ 151=23. „ 2. „ β.

Possible third band. End at 193.

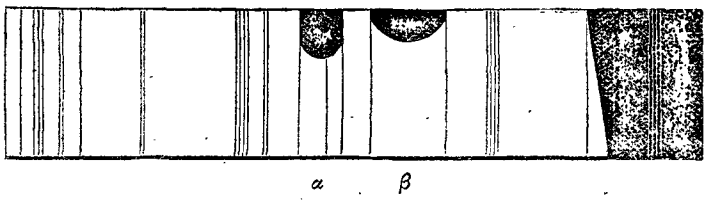


Diagram of Spectrum of Colutea frutescens.

See also Plate II., fig. 6.

Tagetil lucida.

13. *Tagetil lucida.*—Solution slightly fluorescent (?); becomes brilliant by heating.

1. 105 to 120=15. Int. 4. R. α.
Cut off at 130.

Diluted + 1 a second band appears.

2. 131 to 145=14, questionable.
End at 158.

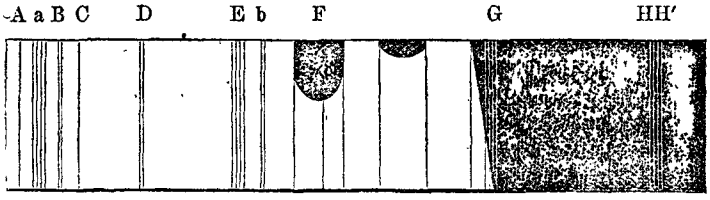


Diagram of Spectrum of Tagetil.

See also Plate II., fig. 7.

Schkuria atrovirens.

14. *Schkuria atrovirens.*—Very pale violet. Absorptions at a minimum.

1. 108 to 123=15. Int. 1.
2. 130 „ 151=21. „ 1.
End at 190.

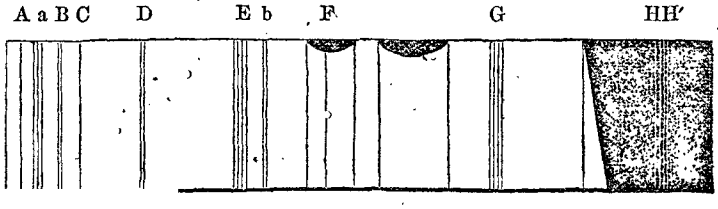


Diagram of Spectrum of Schkuria.

See also Plate II., fig. 8.

15. *Diplotaxis tenuifolia.*—Very pale yellow solution.

Diplotaxis tenuifolia.

1. 113 to 124=11. Int. 2. R. α.
2. 131 „ 148=17. „ 2. „ β.

End at 185.

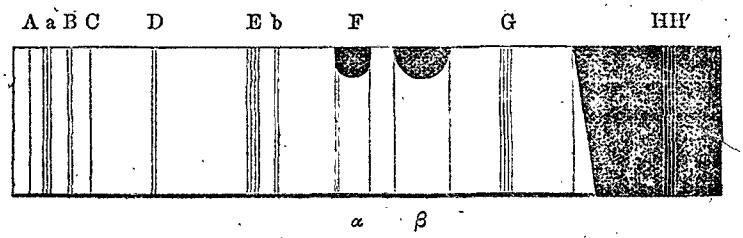


Diagram of Spectrum of Diplotaxis.

See also Plate II., fig. 9.

16. *Virgilia sylvestris.*—Very pale yellow.

Virgilia sylvestris.

1. 114 to 125=11. Int. 3. R. α.
2. 135 „ 153=18. „ 2. „ β.

Questionable third. End at 197.

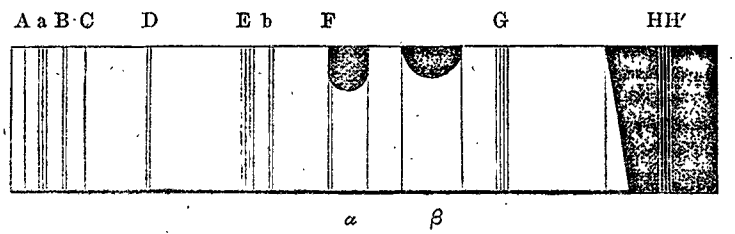


Diagram of Spectrum of Virgilia.

See also Plate II., fig. 10.

17. *Oenothera grandiflora.*

Oenothera grandiflora.

1. 102 to 126=24. Int. 3. R. α.
2. 135 „ 156=21. „ 2. „ β.

End at 178.

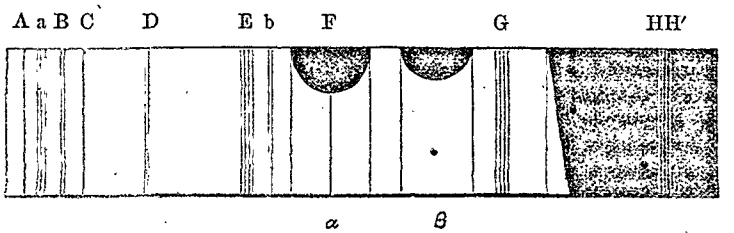


Diagram of Spectrum of Oenothera.

See also Plate III., fig. 1.

Verbascum phlomoides.

18. *Verbascum phlomoides.*—Deep yellow solution. Cut off at 100. Diluted + 1.

1. 112 to 133=21. Int. 6. R. α.
2. 140 „ 163=23. „ 5. „ β.

End about 187. Diluted + 3 at 190. Bands then become very pale.

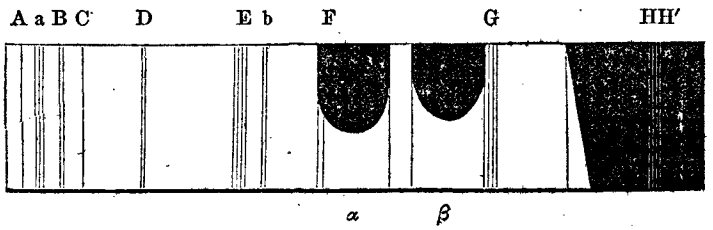


Diagram of Spectrum of Verbascum.

See also Plate III., fig. 2.

Tagetil pumila.

19. *Tagetil pumila.*—Solution turbid.

1. 113 to 125=12. Int. 5. R. α.
2. 133 „ 152=19. „ 2. „ β.

End at 170.

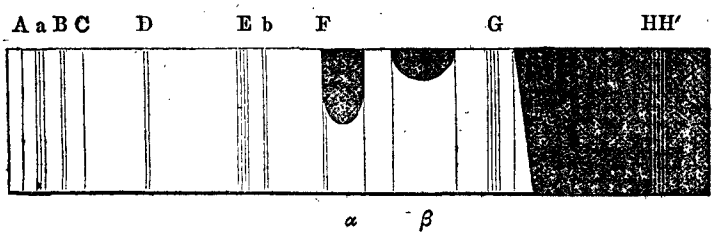


Diagram of Spectrum of Tagetil.

See also Plate III., fig. 3.

Helenium autumnale.

20. *Helenium autumnale.*

1. 107 to 122=15. Int. 5. R. α.
2. 132 „ 152=20. „ 4. „ β.

Dilution produces a suspicion of a third band. End at 190.

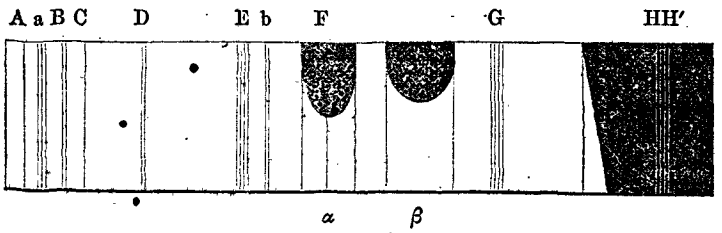


Diagram of Spectrum of Helenium.

See also Plate III., fig. 4.

Linosyris vulgaris.

21. *Linosyris vulgaris.*—Cut off at 108. Diluted + 1.

1. 110 to 125=15. Int. 5. R. α.
2. 135 „ 157=22. „ 3. „ β.

Diluted + 2, suspicion of third band. End at 185.

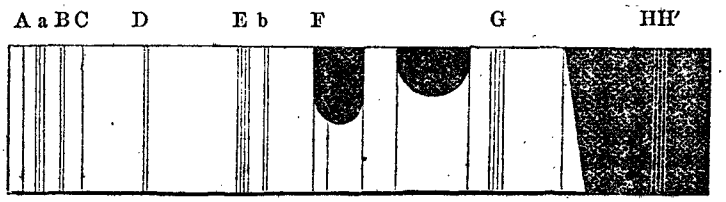


Diagram of Spectrum of Linosyris.

See also Plate III., fig. 5.

Solidago serotina.

22. *Solidago serotina.*—One band appearing diluted + ½.

1. 111 to 124=13. Int. 5. R. α.
2. 134 „ 157=23. „ 3. „ β.

Cut off at 164. Diluted + 3 ends at 185.

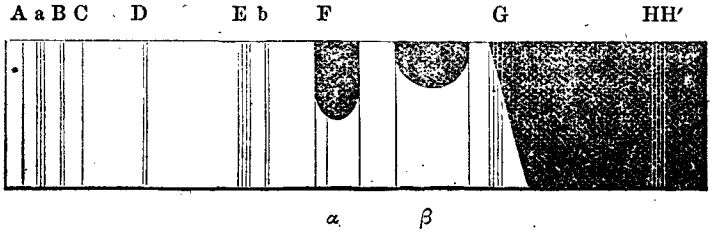


Diagram of Spectrum of Solidago.

See also Plate III., fig. 6.

Ruta graveolens.

23. *Ruta graveolens.*

1. 110 to 125=15. Int. 3. R. α.
2. 133 „ 158=25. „ 3. „ β.

End at 172. Diluted + 1 ends at 185.

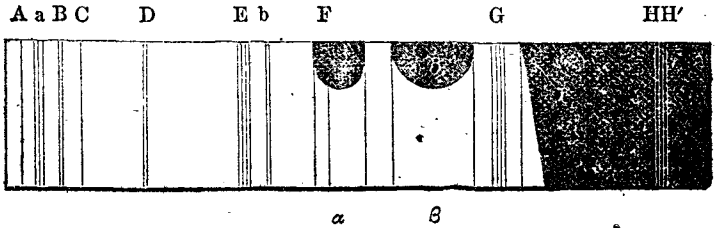


Diagram of Spectrum of Ruta.

See also Plate III., fig. 7.

Melilotus elegans.

24. *Melilotus elegans.*

1. 112 to 125=13. Int. 3. R. α.
2. 135 „ 157=22. „ 2. „ β.

End at 165. Diluted+1 ends at 188.

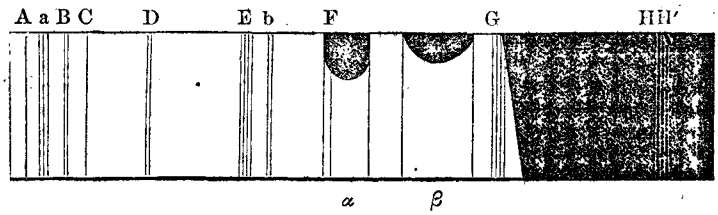


Diagram of Spectrum of Melilotus.

See also Plate III., fig. 8.

Medicago elegans.

25. *Medicago elegans.*—Very dilute solution, layer of 2 ctrs. required.

1. 113 to 126=13. Int. 2. R. α.
2. 135 „ 154=19. „ 2. „ β.

Ends at 163.

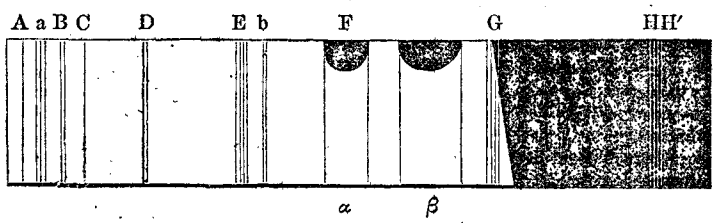


Diagram of Spectrum of Medicago.

See also Plate III., fig. 9.

Allamanda Hendersonii.

26. *Allamanda Hendersonii.*

1. 113 to 125=12. Int. 3. R. α.
2. 134 „ 158=24. „ 4. „ β.

Cut off at 165.

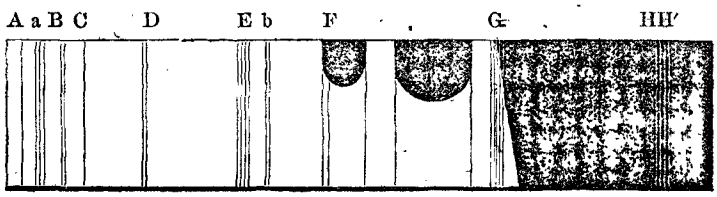


Diagram of Spectrum of Allamanda Hendersonii.

See also Plate III., fig. 10.

In the foregoing I have described all the varieties of luteine yielding two-band spectra which I have been able to meet with in *flowers* during the month of September 1868. I have ranged amongst them all those in which a third band might have been suspected but could not be shown to exist. In the following I am going to describe a series of two-band spectra from other parts of plants, particularly *berries* and *seeds*.

Spectra of berries and reeds.

Asparagus officinalis.

27. *Asparagus officinalis.*—Those who remember the learned essay of the celebrated anatomist Fallopia on the asparagus, will think it fitting that

food for scientific contemplation should be drawn also from the berries of this remarkable plant. The red berries were rubbed with alcohol in a mortar, and the seeds removed. A yellow solution formed, but the red-coloured matter appeared to remain insoluble. The spectrum of this solution was cut off at 115; there was a haze all over the region of blue. The matter was now boiled with water, and after 24 hours filtered. Little coloured matter had dissolved. The red residue was now treated with *warm* alcohol, and yielded all colouring matter easily to the boiling spirit. On cooling a portion of the matter deposited in red flakes. Spectrum of the solution:

1. 110 to 128=18. Int. 3. R. α.
2. 138 „ 156=18. „ 3. „ β.

Possible third band. End at 195.

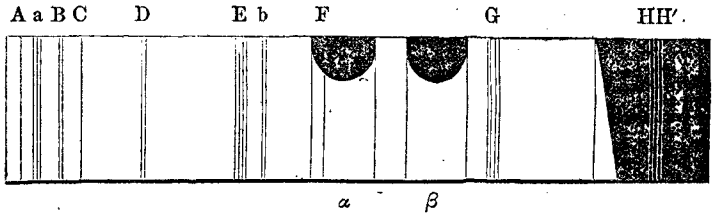


Diagram of Spectrum of Asparagus Berries.

Compare also Plate IV., fig. 1.

28. *Physalis Alkekengii.*—The husk of the berry is a wide red bag. Physalis Alkekengii.

1. 104 to 120 =16. Int. 3. R. α.
2. 129 „ uncertain=18. „ 1. „ β.

Solution 2 ctrs. thick. No bands in layer of ctr.

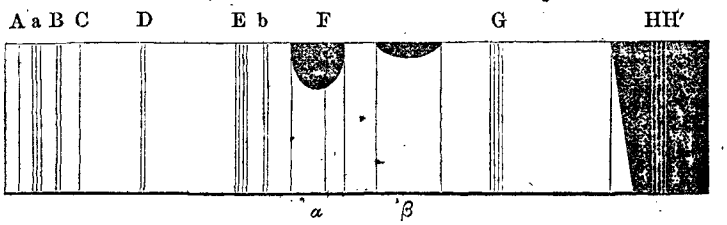


Diagram of Spectrum of Husk of Physalis Berry.

See also Plate IV., fig. 2.

29. *Solanum Dulcamara Berries.*—Solution saturated yellow to orange. Solanum Dulcamara.

1. 107 to 122=15. Int. 2. R. α.
2. 128 „ 151=23. „ 2. „ β.

Suspected third. End at 190.

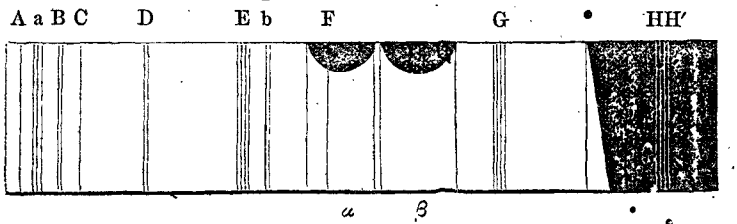


Diagram of Spectrum of Solanum Dulcamara Berries.

Compare Plate IV., fig. 3.

Solanum capsicastrum.

30. *Solanum Capsicastrum Berries.*—Pale yellow solution. *Fluoresces distinctly,* and in that respect is the only yellow substance showing detached bands which I have met with.

1. 106 to 120. Very pale } Solution 3 ctrs.
2. 130 „ 149. do. } thick.

Ends at 188.

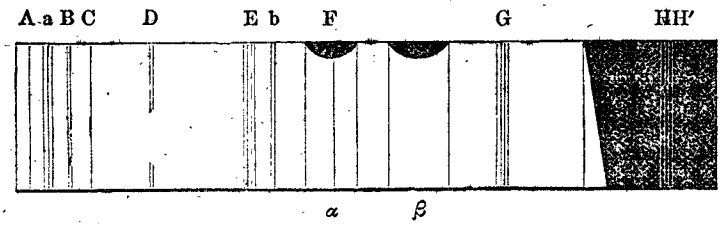


Diagram of Spectrum of Solanum Capsicastrum Berries.

See also Plate IV., fig. 4.

Cyphomandra betacea.

31. *Cyphomandra betacea.*—Large oval berry. Solution pale yellow. Layer 3 ctrs. thick.

1. 103 to 114=11. Int. 3. R. α.
2. 125 „ 145=20. „ 2. „ β.

Ends at 163.

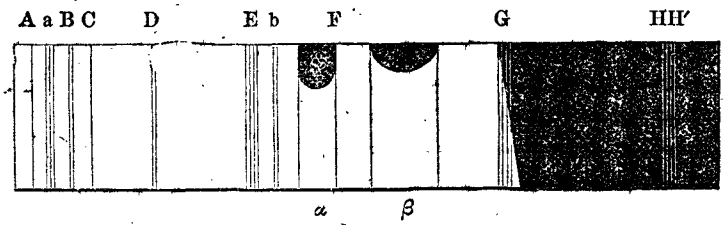


Diagram of Spectrum of Berry of Cyphomandra.

See also Plate IV. fig. 5.

Cratægus cnut Galli.

32. *Cratægus cnut Galli Berries.*—Red solution 2½ ctrs. thick. Cut off at 97.

1 ctr. thick pale yellow, shows spectrum:

1. 102 to 114. Int. 1.
2. 124 „ 142, „ 1.

Ends at 180.

2 ctrs. thick it shows spectrum:

1. 100 to 116 = 16. Int. 4. R. α.
2. 124 „ 148 = 24. „ 3. „ β.

Ends at 160.

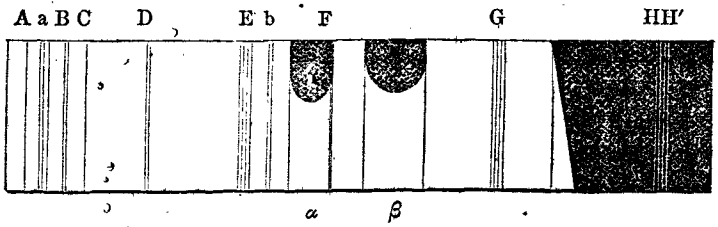


Diagram of Spectrum of Berries of Cratægus.

See also Plate IV., fig. 6.

33. *Pyrus Aria Berries.*—Yellow solution, 2 ctrs. thick. Pyrus Aria.

1. 103 to 118 = 15. Int. 4. R. α.
2. 126 „ 147 = 21. „ 3. „ β.
Ends at 163.

With a layer of 1 ctr. thick bands disappear and end at 190.

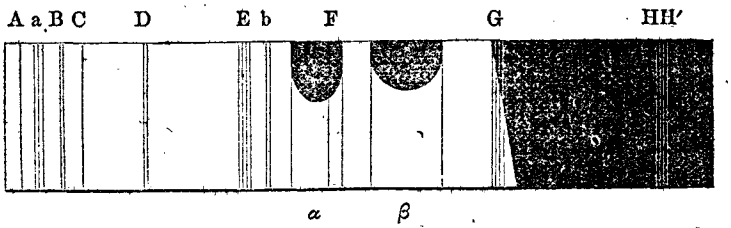


Diagram of Spectrum of Berries of Pyrus Aria.

See also Plate IV., fig. 7.

34. *Zea Mais or Indian Corn;* Seeds.—The powdered seeds treated with warm alcohol yielded a golden yellow solution which became turbid on cooling; it shed a deposit on standing and then was clear. The very concentrated solution showed red and yellow, and was cut off at 105. First probable band on slight dilution, 105 to 123. More dilute solution, 1. 107 to 118; 2. 128 to uncertain. A more clear but more dilute solution 2 ctrs. thick showed, 1. 107 to 118; 2. 128 to 147. Ultimately the following measurements were adopted as final: Zea Mais.

1. 108 to 122 = 14. Int. 2. R. α.
2. 128 „ 148 = 20. „ 2. „ β.

Last line difficult to read and somewhat doubtful.

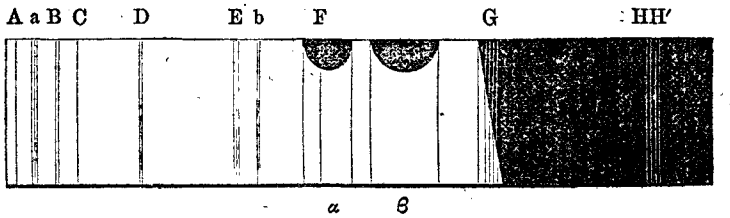


Diagram of Spectrum of Maize Seeds.

See also Plate IV., fig. 8.

These bands, therefore, are the same almost as those of the alcohol solution of ovario-luteine, which read—

1. 107 to 120.
2. 128 „ 149.

There is a matter contained in the extract of the seeds which absorbs entirely the violet end where a third band might possibly appear, and does appear in the animal, and some vegetable luteine solutions.

d.

Three-banded Luteine Spectra.

I pass now to a series of vegetable spectra which most closely resemble the spectra of animal luteine already described. In some of them the Three-banded luteine spectra.

APPENDIX.

No. 6.
On Chemical Identification of Disease, by Dr. Thudichum.

Common carrot, Carotine.

third band is less distinct than in the animal luteines, in others it is more distinct, and the whole of the three-banded spectra have therefore on plate IV., fig. 9 and 10, plate V., fig. 1 to 10, and plate VI., fig. 1 to 3, been arranged in accordance with this progression of distinctness.

Daucus carrota, Common carrot-root.—The colour of the carrot is due to a particular matter termed *carotine*, $C_{18} H_{24} O$. It is reddish-brown in crystals, crystallises in cubes, smells like the Florentine violet-root, and with concentrated sulphuric acid becomes blue, and dissolves with the same colour. However similar, therefore, the spectrum of carotine may be to that of the animal luteines, its chemical properties seem to be different. Carotine heated to 150 becomes reddish-brown, and in that state is the substance to which so-called cichory, or chicory, owes its tinctorial qualities and fraudulent use.

Some carrots were scraped and extracted with warm alcohol. The yellow solution on cooling became opaque and was again filtered.

1. 103 to 120 = 17. Int. 5. R. α.
2. 128 „ 149 = 21. „ 5. „ β.

End at 160. Dilution + 1 extended violet to 197, and there appeared a feeble band.

3. 165 to 180 = 25. feeble 5 R. γ.

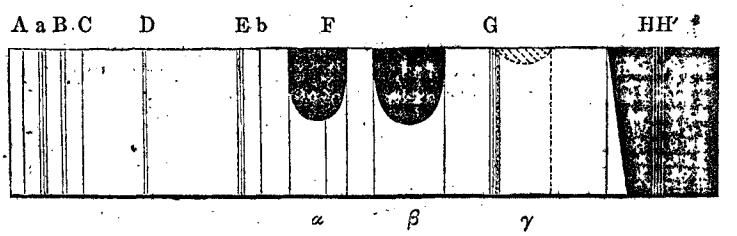


Diagram of Spectrum of Common Carrot.

See also Plate IV., fig. 9.

Bixa orellana, or Annatto.

Annatto, or *Orlean*, the flesh of the fruit of *Bixa orellana*, a South American tree. It occurs in trade as a plastic red paste. It contains perhaps two colouring matters, of which *orelline* is the least characterised. *Bixine* is the main dyeing ingredient; it is little soluble in water, easily in alcohol and ether, with orange colour. Concentrated sulphuric acid colours it *blue*, next *violet*; nitric acid changes it to green, ultimately yellow. A concentrated alcohol solution of orange colour cut the spectrum off at 77. On dilution the absorption gradually receded towards 89, further to 92. When more diluted, so that the solution was yellow, absorption receded to 103. Again diluted to light yellow, a spectrum of bands appeared:

1. 105 to 121 = 16. Int. 5. R. α.
2. 132 „ 148 = 16. „ 4. „ β.
3. 167 „ 178 = questionable.

Blue to 203.

At a particular dilution, with strongest Drummond's light I measured finally—

1. 106 to 124 = 18. Int. 5. R. α.
2. 129 „ 153 = 24. „ 5. „ β.
3. 162 „ 181 = 19. „ 1. „ γ.

End at 205.

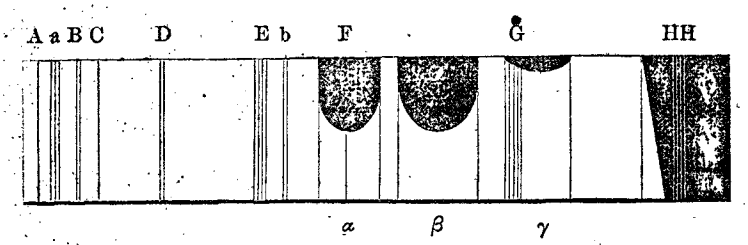


Diagram of Spectrum of Annatto, or Bixine.
See also Plate IV., fig. 10.

Annatto is used for dyeing silk. Most English cheese is dyed with annatto and turmeric.

Calendula officinalis, Common Marigold.—The cold alcoholic extract has a splendid yellow colour. Like the extract of calceolaria, the concentrated solution cuts the spectrum off at blue. Diluted there appears— Calendula, Marigold.

1. 109 to 123 = 14. Int. 3. R. γ. Sharply cut off at 127. On dilution second band appears, which has now treble the strength of the first, which latter becomes int. 2.

2. 129 to 146 = 17. Int. 5. R. α.
3. 156 „ 177 = 21. „ 5. „ β.

End at 189.

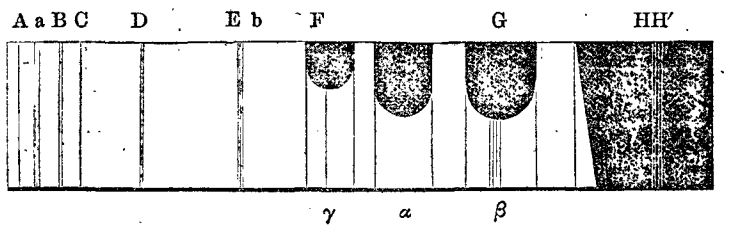


Diagram of Spectrum of Flower of Marigold.

Again diluted band 1 almost disappears, and 2 and 3 remain of int. 2. In this spectrum the three bands are most distinct, but the distribution of intensity is most peculiar.

Chrysopsis villosa. Chrysopsis villosa.

1. 109 to 120=11. Int. 8. R. α.
2. 131 „ 154=23. „ 5. „ β.

Diluted + 1 there appears—

3. 167 to 183=16. „ 1. „ γ.

End at 200.

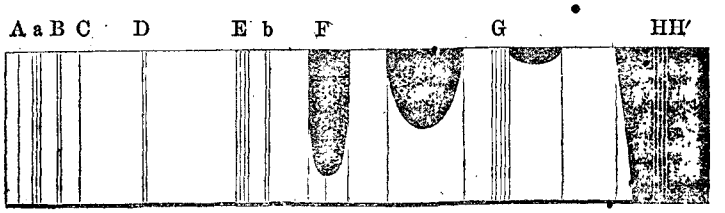


Diagram of Spectrum of Chrysopsis Flower.

Obliscaria pinnata.

Obliscaria pinnata.

1. 108 to 122=14. Int. 4. R. α.
2. 131 „ 154=23. „ 3. „ β.
3. 165 „ 185=20. „ 1. „ γ.
End at 193.

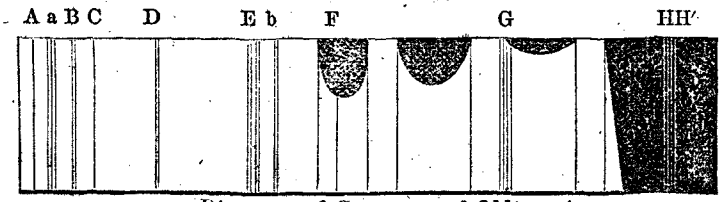


Diagram of Spectrum of Obliscaria.

Heliopsis lævis.

1. 107 to 124=17. Int. 5. R. α.
2. 131 „ 155=24. „ 3. „ β.

Diluted + ½.

3. 164 „ 182=22. „ 1. „ γ.
End at 192.

Heliopsis lævis.

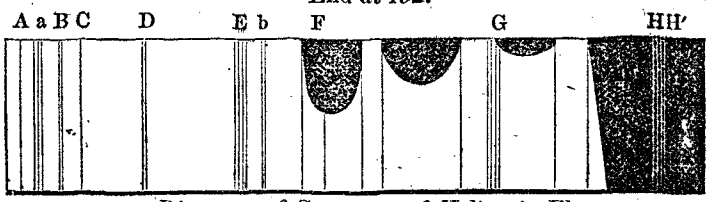


Diagram of Spectrum of Heliopsis Flower.

Plate I. to V. are described in the text of chapter N, pp. 183–216; each spectrum is identified by the name of the substance from which it is derived.

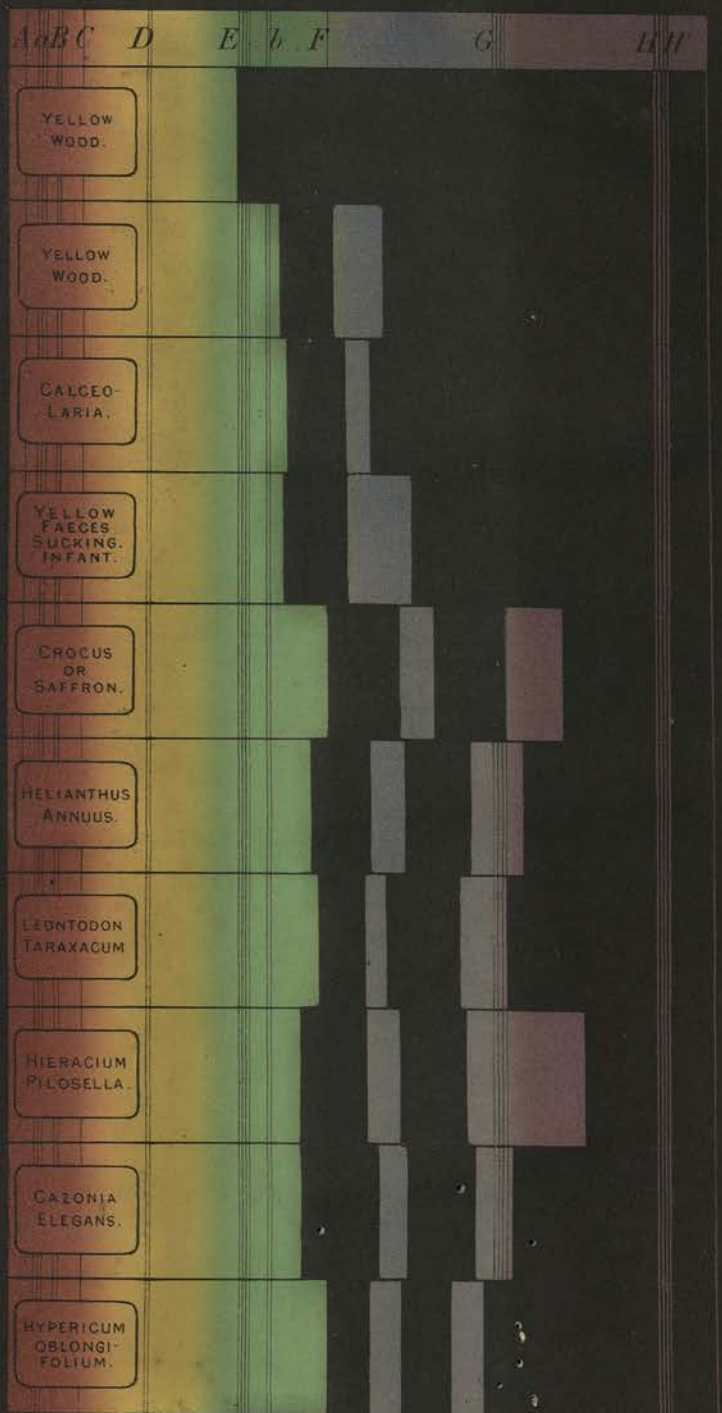
Plate VI. Crystals of cholophaeine or bilirubine (see Eighth Report of the Medical Officer, 1868).

Plate VII. Crystals of ovario-luteine.

Plate VIII. The measurements of spectra in the cholera report 1867, were given in minutes and degrees of a quadrant of the disk of the spectrometer. After the construction of the new spectrometer and observatory, described in the report for 1868, I adopted a more convenient scale of 245 divisions, of which 20 project into the caloric region, and 25 into the fluorescent or metachromatic region, while 200 were made to divide equally the visible chromatic spectrum, the line 60 being made to coincide with the middle of the D line. This scale is represented on the left of the explanatory drawing (plate viii); on the right is given the scale of 1867, and between both are the principal sun-lines in the accurate position in which they would be indicated by either scale. All spectra in my three reports are of the same standard length with reference to the sun-lines, and consequently can be expressed in points of either scale. One scale can be easily transformed into the other empirically, by means of a pair of compasses on the explanatory drawing of plate viii.

The indications of any scale whatever can be transformed into the corresponding ones of any other by the method of Steinheil. The two scales are united at their zero point at a right angle, and a diagonal is erected in the angle between them, the position of which is determined by the point of section of two perpendicular lines erected on two corresponding points, say D and D′. The corresponding points of each scale are then determined by the points in the diagonal in which any two perpendiculars from the scales cut each other. (For particulars and drawings, see Carl, Repert. f. physik. Technik, vol. 1. p. 85, and Atlas plate xi.g. 10 and 11.)

Plate I.



Dr Thudichum Inven. et direxit

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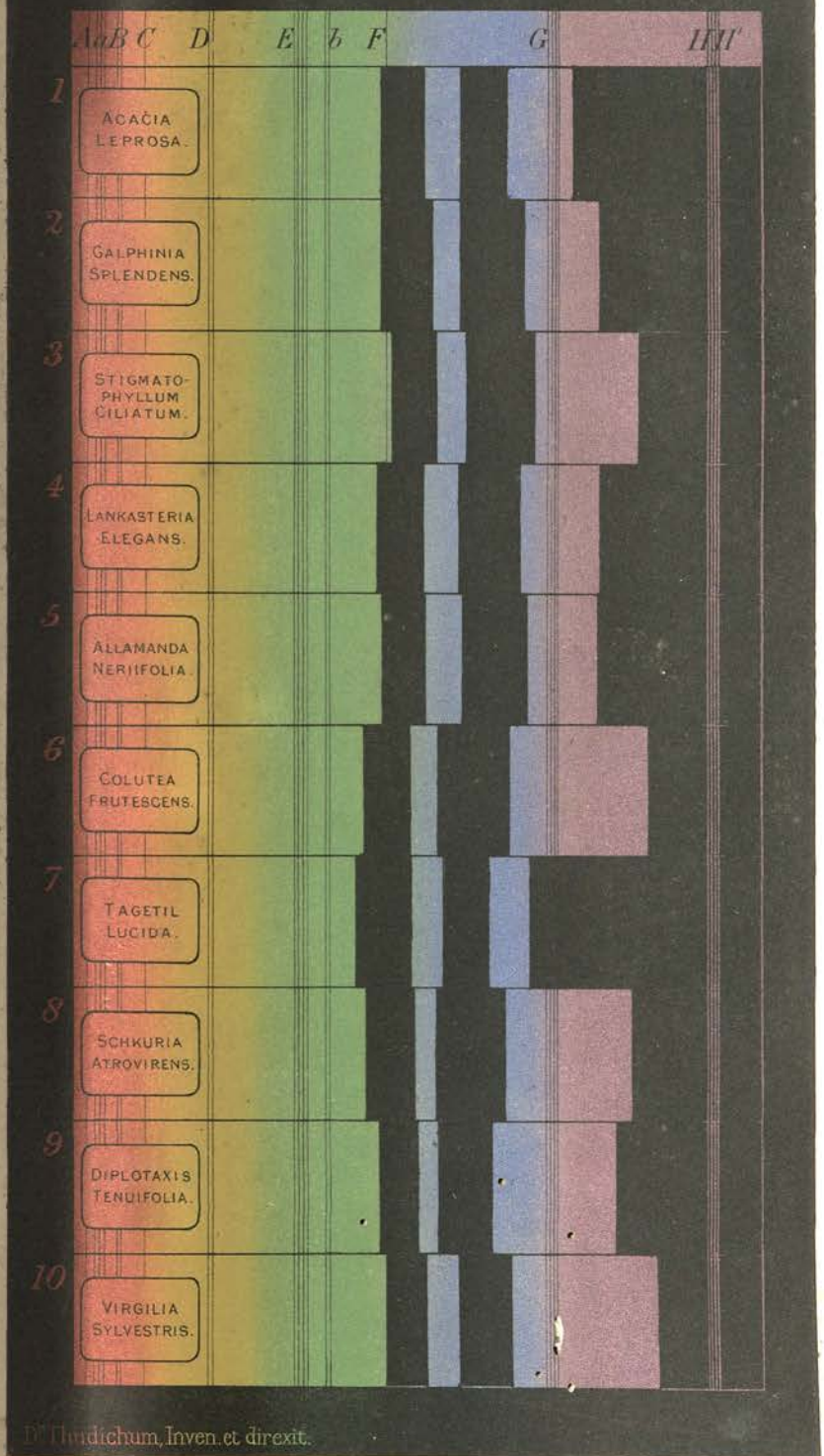
Plate II.



Dr Thudichum, Inven. et direxit.

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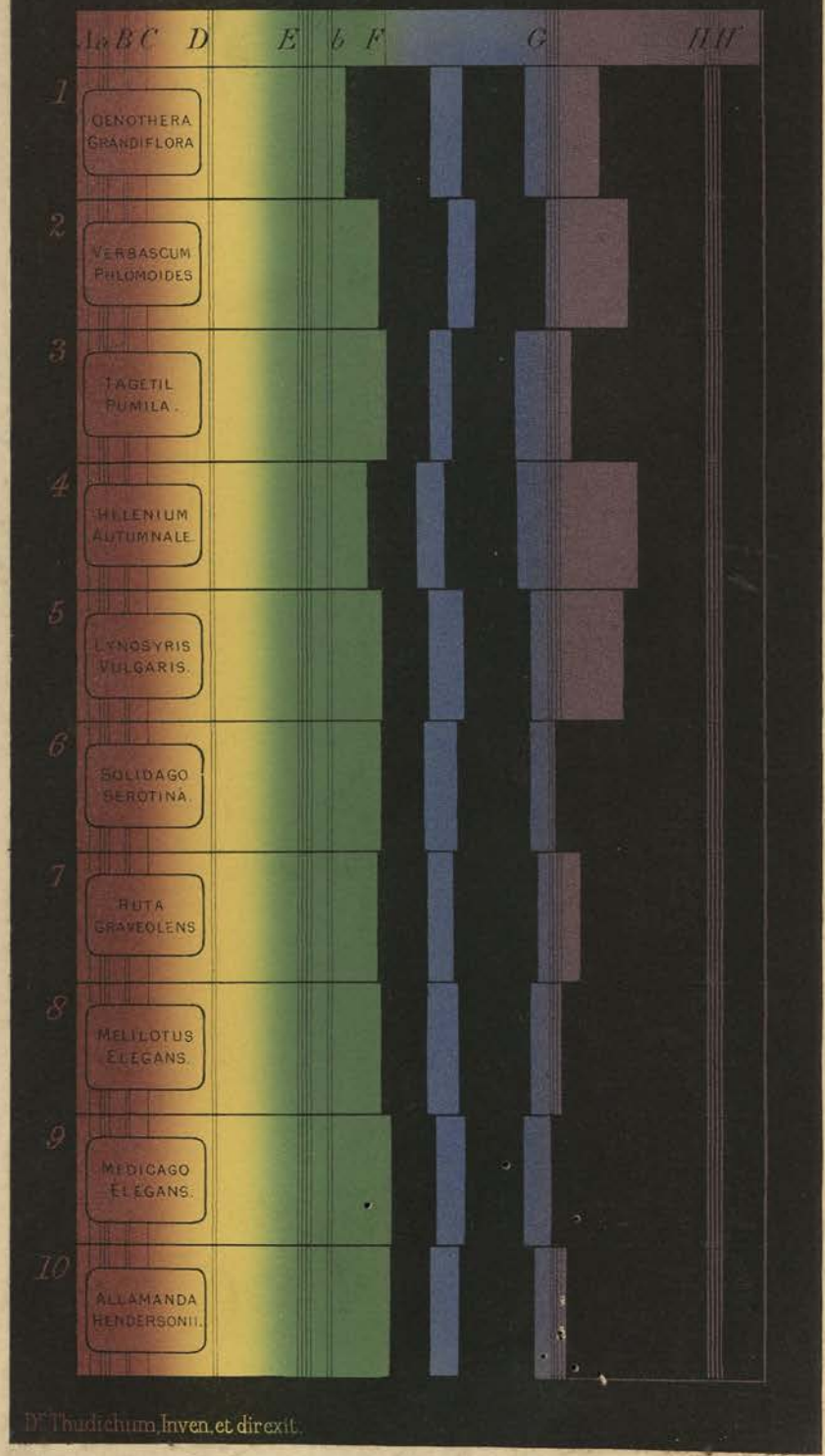
Plate III.



Dr. Thudichum, Inven. et dir. exit.

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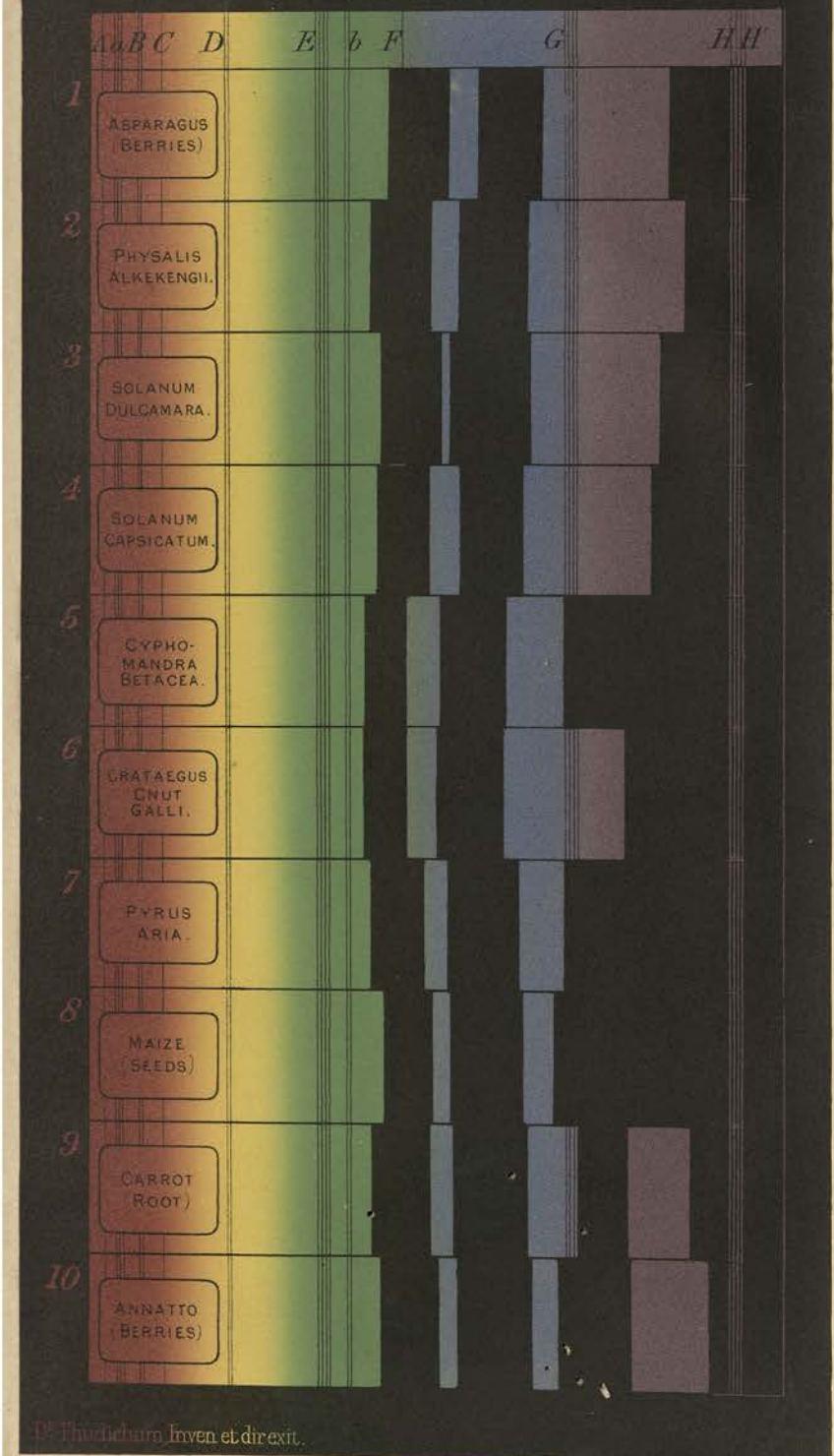
Plate IV.



Dr Thudichum Inven et dir exit.

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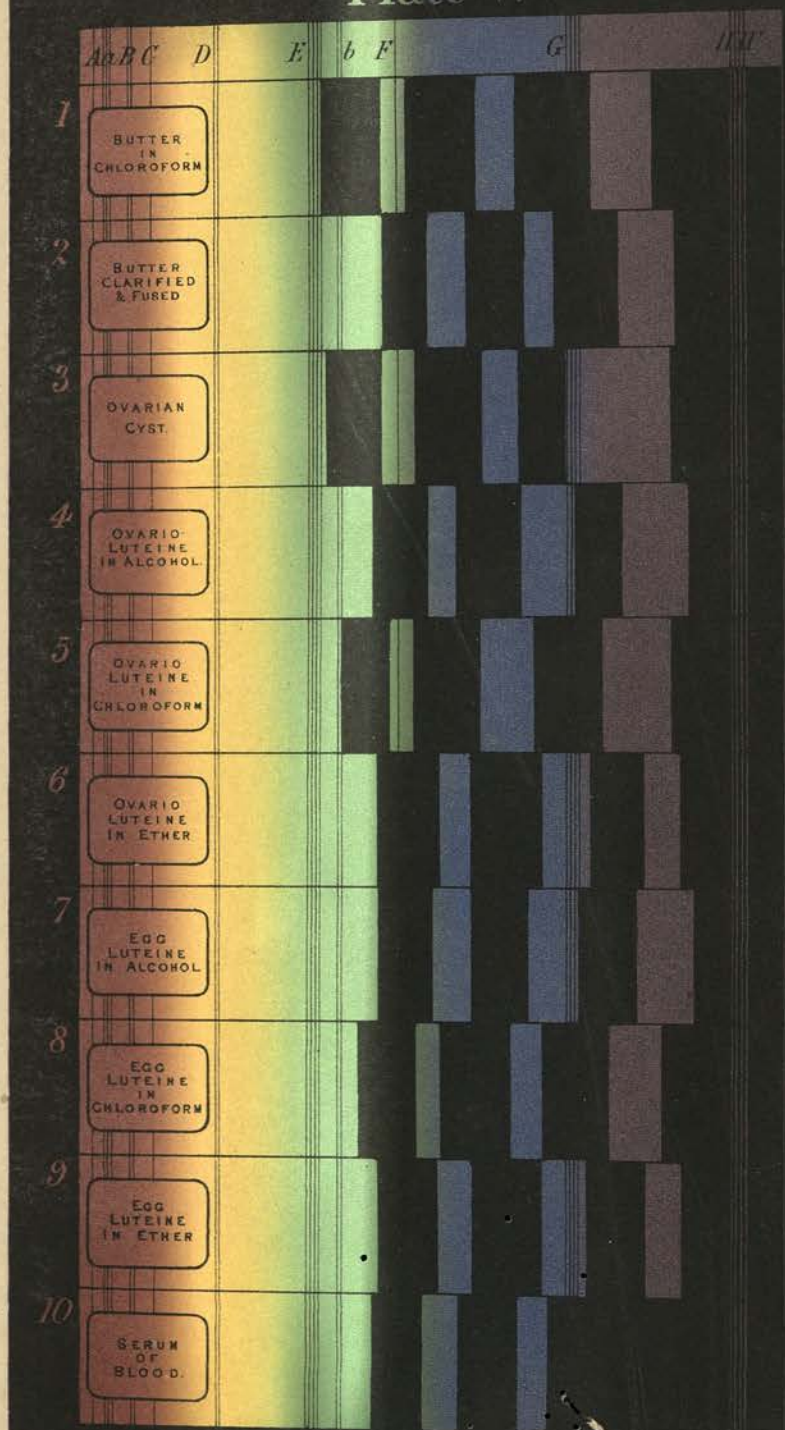
Plate V.



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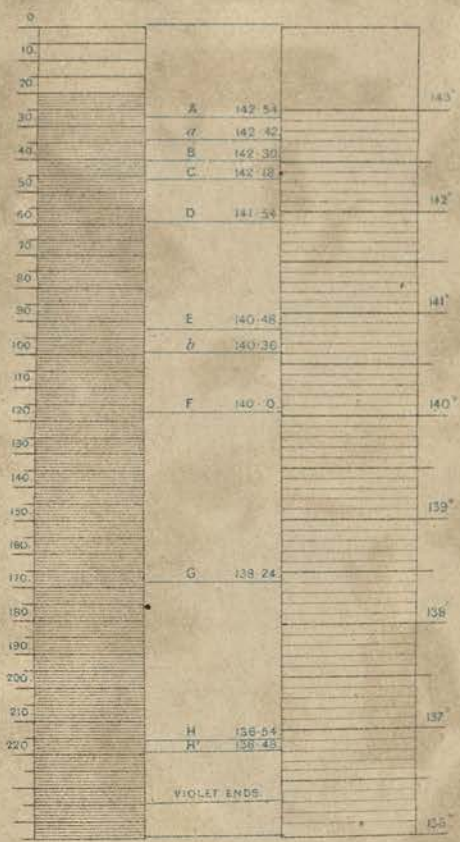
Dr Thudichum, Inven. et Direxit. J. Buckley, Pinxit.

Vincent Brooks Day & Son, Lith.

COMPARISON OF FORMER AND PRESENT
SPECTRO-SCOPICAL SCALES.



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